TDMA

User Manual

Revision 3.0U
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FreeWave Technologies, Inc
1880 South Flatiron Court
Boulder, CO 80301
USA
Ph. (303) 444-3862

Needs discussion of frame table size set to 109 to satisfy fcc requirements, at 112 with an "even" frame table, you end up with an aliasing effect where the radio actually only hops on 56 frequencies. With either an odd hop table, or an odd frame table, things shift in time and fcc requirements are met.

About this document

General information

This document covers the TDMA protocol available with the FreeWave spread spectrum transceivers.

Revision History

Table 1 shows revision history of this document

Table 1. Revision History

Revision	Date	Description
1.0	Jun 5th 2001	First release.
3.0m		
3.0n	Nov 15, 2001	
3.0o	Sept 11, 2002	
3.0p		
3.0q	Dec 3, 2002	Misc. in examples, frame table, commands.
3.0r	Aug 4, 2003	Addition of special packet command parameters.
3.0s	Oct 28, 2003	Fixed total frames in epoch discussion. Added mention of RF data rate in setup parameters.
3.0t	Dec 9, 2003	Added firmware version table.
3.0U	Feb 13, 2004	Added note of no local operation to signal quality and status packets. Added description of retry timeout.

How to contact us

We can be reached at:

FreeWave Technologies, Inc.
1880 S. Flatiron Court, Suite F
Boulder, CO 80301
Ph. (303) 444-3862
Fax (303) 786-9948
www.freewave.com

General info e-mail:

Moreinfo@freewave.com

Contents

FreeWave TDMA general description

The FreeWave Time Division Multiple Access (TDMA) protocol is an enhanced and sophisticated version of point to multipoint communications. The TDMA protocol provides timing and other parameters, which in turn allow large networks of radios to work in a non polled environment. This would be useful, for example, in a network of GPS stations. If the GPS receivers report in an un-polled manner, numerous packet collisions would occur if a standard multipoint network was used. The TDMA protocol provides the timing parameters to allow each radio to report in at a predetermined time.

The basic concept of the TDMA protocol is that each radio within a network is assigned a specific time slot to transmit a message, receive a message, repeat another radio's message, or do nothing. 1 to 16 slots can be assigned to either a *slave frame* or a *master frame*. A single master frame and 1 to 15 slave frames can be assigned to a *frame casing*. A number of frame casings are assigned to an *epoch*. An epoch is the complete sequence of slots, frames, and frame casings that continually cycle. Figure 1 illustrates this concept.

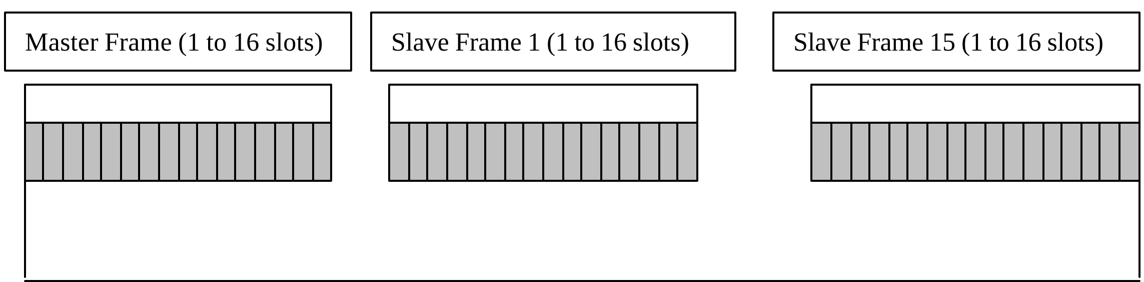


Figure 1 Frame Casing

One Master Frame with 1 to 15 Slave Frames makes one frame casing. One or more of these frame casings make an epoch.

The design goal of the TDMA protocol was to give the user a maximum amount of optimization for the application. This is accomplished by having a *transparent mode* and *packetized mode*. Packetized mode requires the use of a header packet to direct messages or commands to a specific radio or to all radios. Packetized mode can be used in a poll environment and has no limit on the number of slave radios in the network. Radios specifically addressed in the header packet will send the received information

out the RS-232 port. If all radios have been addressed by doing a broadcast all, all radios listening will receive information and will transfer it to the RS-232 port.

Transparent mode is most commonly used with devices, which are not capable of generating header packets. Therefore, all data received from the RS-232 port is broadcasted to every listening radio. When the data is received by a radio operating in transparent mode, the data sent to the RS-232 port does not have a header packet associated with the data. Each slave radio has a frame assigned to them in which they are allotted a time to transmit data. Therefore, the number of slave radios allowed in a transparent environment is limited to 255. However, in some applications this number might be higher. For example, if some of the slaves in the network do not transmit data and only listen to the master.

A network can be a combination of transparent mode and packetized mode radios. One of the most common networks consists of a master radio being setup in packetized mode and the slaves set up in transparent mode. This type of setup allows the master to issue commands to the listening slaves. Having the slaves in transparent mode allows the user to connect devices that cannot identify themselves by building header packets.

The FreeWave TDMA network provides a 'best effort' transport meaning that delivered packets are guaranteed to be error free, but packets containing errors are discarded. No error correction mechanism is implemented in the TDMA network itself. All packets must pass a 32-bit CRC check before the packet is sent out the RS232 port. Data is guaranteed to be accurate, but not guaranteed to be received.

RS-232 data must be sent to the radio following the state of the CTS line, and must be received before the system slot to be transmitted in the following frames. Even when there are multiple frames per frame casing for a particular radio, all data for that frame casing must be received before the system slot.

Definitions

Slot

A slot is a period of time in which a single message is transmitted, received, or repeated by a particular radio. The duration of this message is a user-defined setting and may range from 8 to 240 bytes. A radio, which is assigned a particular slot, will always transmit at least a header packet regardless of data. It takes 1 to 16 slots to make a frame (refer to Figure 1). There are two types of slots - master slot and slave slot. All slave slots are the same size. The master slot and slave slot byte sizes do not need to be identical.

Master slot

The Master slot occurs as the very first slot of a master frame. The maximum number of data bytes within this slot can be set differently than a slave's slot. The number of bytes can range from 8 to 240 bytes. A master radio will always transmit at least a header packet regardless of data present in the first slot of a master frame.

System slot

A system slot is a special slot that occurs before the master frame. It is transparent to the user and is only used by the system to allow the radios to finish processing before proceeding to the next frame casing. The system slot can also be used to insert a small amount of dead time to make the overall timing within the network match some external clock. If used to extend the time for timing issues, there will not be any radios transmitting during this slot.

Frame

A frame is a grouping of 1 to 16 slots. All slots within a frame are the same size. A master frame and a slave frame are the only type of frames. Refer to Figure 2. The frame is used to assign a specific task to a radio. A task can consist of telling the radio to transmit, listen, do nothing or repeat.

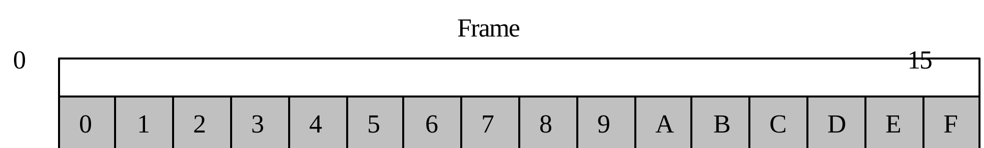


Figure 2 Frame Dissection

Master frame

The frame number 0 is a master frame. During this frame there can be up to 15 repeating slots, each of which is the same size as the master slot. A master frame occurs every 1 to 15 frames. The master and submasters use the master frame to synchronize the timing of the entire network and to send data packets. Every radio within the network must be able to hear the master or any submaster to remain active within the system.

Slave frame

A slave frame is a fixed number of slots that follows the master frame. Every frame except the one master frame is termed a slave frame. There can be up to 15 repeating slots within a slave frame. Given the fact that all of the radios in the network synchronized to the master, a radio transmitting in a repeating slot need not hear the originating slave radio as long as it hears one repeater before it.

Frame casing

A frame casing consists of one master and one to fifteen slave frames. The master frame is always the first frame of a frame casing and is always followed by at least one slave frame. There can be different frame casings in the system, but it must always have the same master frame and the same number of slave frames. The slave frame functions can vary from frame casing to frame casing as long as the total number of these frames do not vary. Figure 3 shows an example of a frame casing.

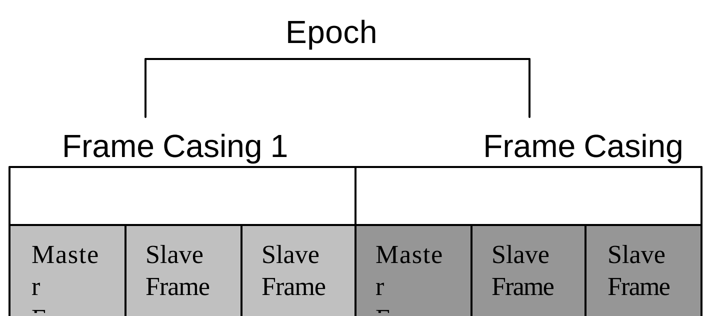


Figure 3 Epoch disection.

Each Frame casing starts with a master frame followed by slave frames. One or more frame casing makes up an Epoch.

Epoch

An Epoch is the period in which an integral multiple of master frames is transmitted before everything is repeated. An epoch can be as little as 1 frame casing or as many as 255 frame casings. There can be no more than 255 slave frames in an epoch. The total number of frames in an epoch is equal to the number of master frames plus the number of master frames multiplied by the number of slave frames. Alternatively, the total number of frames in an epoch is equal to the number of frames during a frame casing multiplied by the number of master frames. See Figure 3 for an example of an epoch consisting of two frame casings.

Master

The master is the radio used within the TDMA network for synchronization. Only one radio within the network can be assigned to be a master. Every radio within the network must hear the synchronization signal either directly or through a submaster. The master always transmits on the first slot of a master frame. The master can also be a slave or a slave repeater during a slave frame.

Submaster

A submaster is a radio that repeats a master in a master frame. A submaster does not need to hear the master directly as long as it hears one submaster before it in the same master frame. A submaster will obtain its synchronization only from the master or a preceding submaster. A network can have a maximum of 15 submasters.

Slave

A slave is a radio, which originates messages and synchronizes itself with a submaster or the master. A slave radio can act as a repeater for other slaves in any frame, which is not the originating radio.

Slave repeater

A slave repeater is a radio that repeats a slave transmission within a slave's frame. Repeaters are assigned a specific slot within the slave frame to repeat any messages heard in a preceding slot. A radio cannot transmit an originating message and then repeat it in the same frame. The repeater does not need to hear the original message from the slave as long as it hears one repeater before the assigned transmission slot. Note that a slave can be, and often is, a repeater in any frame that is not the originating radio. A repeater will obtain its synchronization and must periodically hear from a master or one of the submasters.

Assigned data and immediate data

When the data packet is received from the RS232 port, radio will process it during the system slot time and may transmit it as assigned data or as immediate data based on local radio settings.

Transmitting data packet as assigned data assures that the packet will be send out during radio's assigned frame as setup in the frame table. The assigned data transmission mode is the most common data type for TDMA. An originating message will always be transmitted on the slot number 0 of the assigned slave or master frame.

Immediate data means that the local radio will pick up a random slave frame within the nearest new frame casing for its transmission. In this mode the packet is transmitted only one time regardless of the *MasterPacketRepeat* settings and can be transmitted during a slot that is assigned to a different radio since it transmits on a random slave frame.

Packetized mode

Packetized mode allows commands to be sent and received by the radios within a TDMA network. This gives the user added flexibility and the power of TDMA to solve a variety of application problems. If the radio is set to packetized mode, all messages transferred from the RS-232 port to the radio must be formatted into a data packet with a header. All packets transferred from the radio to the RS-232 port also have a header attached so the user can utilize the information contained in the header. Radios can be configured for transparent mode and packetized mode within the same network. Packetized mode also allows dynamic allocation of frame configuration for each individual radio in the network.

Transparent mode

Transparent mode is transparent to the user. All packets transferred to or from the radio to the RS-232 port are strictly data with no header attached. Each RF packet transmitted contains a 5-byte header packet, which includes the delimiter character, the three-byte serial number of the radio, and the number of characters within the data message. A radio in transparent mode that receives a transparent or packetized packet, strips off the header packet before it is transferred out to the RS-232 port of the radio. A radio in packetized mode that receives a message from a transparent mode radio transfers the header packet along with the data message out the RS-232 port of the radio.

Local radio

Local radio is a radio, which is connected through the RS232 port to equipment that generated a command or data to be evaluated by the radio.

Remote radio

Remote radio is a radio, which is a part of the same TDMA network with the local radio and which potentially can hear transmissions from the local radio directly or through a repeater(s)/submaster(s).

Original and temporary frame tables

Each radio in the TDMA operation mode stores its frame table in two different memory blocks. The original frame table is stored in the EEPROM and can be viewed and edited from the TDMA menu. This table is a hard copy of the frame table, which assures that the radio will return to a known state after each power-on-off cycle. When the DC power is applied to the radio, the radio creates an exact copy of the original frame table in the RAM. This copy is named a 'temporary frame table' and will be used by the radio from that moment until the next power-on-off cycle. The temporary frame table can not be edited from the TDMA menu, but the whole table or any part of it can be changed and edited by using special commands if the radio is in the packetized mode. Moreover, this frame table can be reset back to the original frame table or can be kept after radio looses synch to a master depending on the *FrameTable Reset on Disconnect* settings.

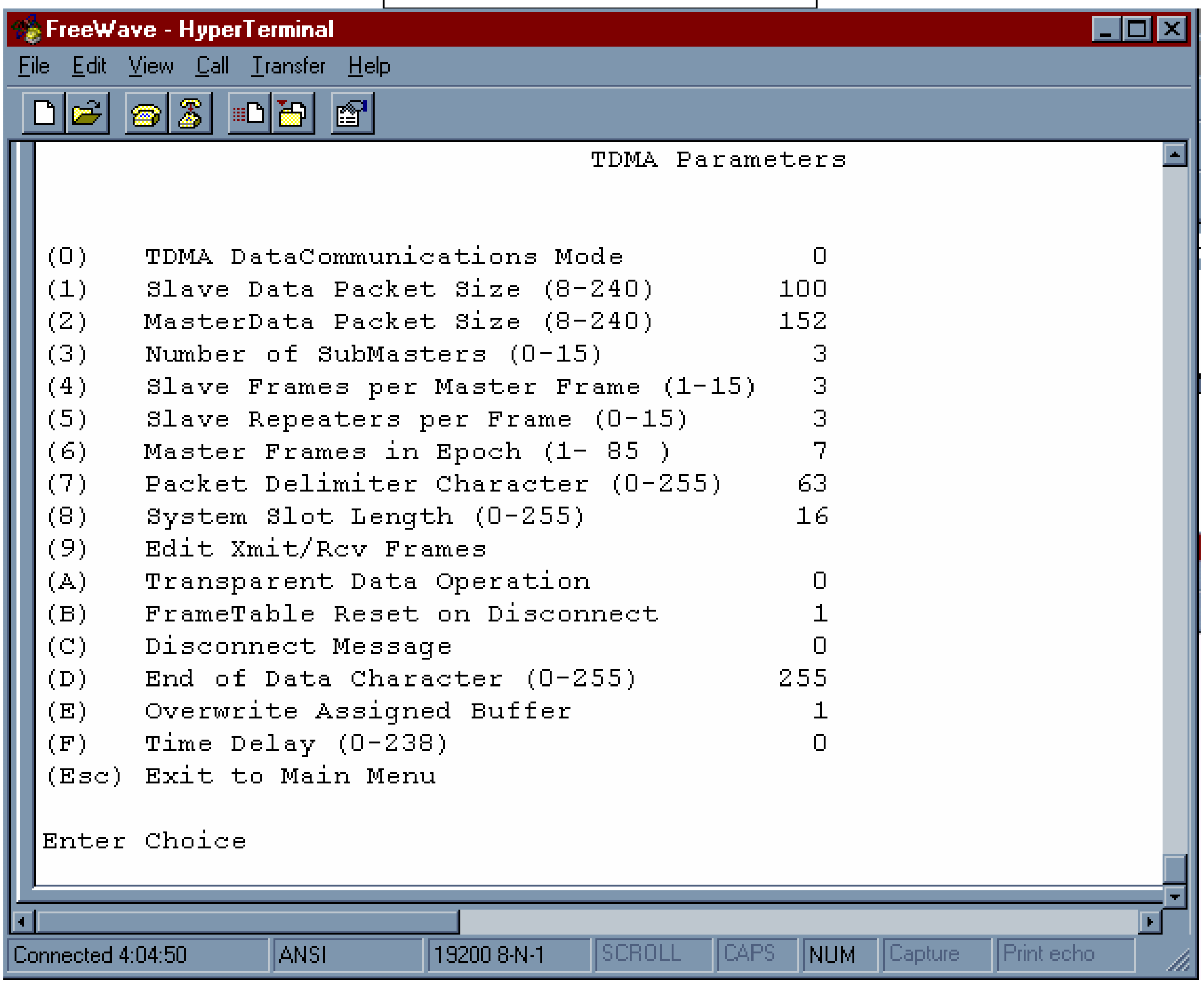
CRC

Cyclical Redundancy Check. The FreeWave Radios implement a 32 bit CRC check on all data packets to guarantee correct data.

TDMA Setup Parameters

The TDMA mode is activated by entering the radio's setup mode and selecting option zero from the menu. Once in the Operation Mode menu enter 8 for TDMA. Escape back to the Main menu and enter 6 for TDMA parameter menu. Refer to Table 1 for an example TDMA parameter table.

Table 1 TDMA Parameters List



TDMA Parameters

(0)	TDMA DataCommunications Mode	0
(1)	Slave Data Packet Size (8-240)	100
(2)	MasterData Packet Size (8-240)	152
(3)	Number of SubMasters (0-15)	3
(4)	Slave Frames per Master Frame (1-15)	3
(5)	Slave Repeaters per Frame (0-15)	3
(6)	Master Frames in Epoch (1- 85)	7
(7)	Packet Delimiter Character (0-255)	63
(8)	System Slot Length (0-255)	16
(9)	Edit Xmit/Rcv Frames	
(A)	Transparent Data Operation	0
(B)	FrameTable Reset on Disconnect	1
(C)	Disconnect Message	0
(D)	End of Data Character (0-255)	255
(E)	Overwrite Assigned Buffer	1
(F)	Time Delay (0-238)	0
(Esc)	Exit to Main Menu	

Enter Choice

Following is a brief description of the TDMA parameters:

(0) TDMA Data Communication Mode (0/1):

Note: This parameter can be mixed across the radio network.

(0) **Transparent Mode:** Data is transferred to and from the RS-232 port without a header packet. This mode allows relatively ‘dumb’ devices to transfer data to and from the radio without the need to compile or de-compile the header information.

(1) **Packetized Mode:** All data to and from the radio begins with a header that contains delimiter, addressing and/or a command and the data. Therefore, the device connected to the radio in packetized mode must be capable of compiling or de-compiling a header packet, which is associated with the data.

In general, there are two types of information that can be sent to the radio in a packetized mode – command or data. A command can be addressed to a local radio or to a remote radio. The data can be broadcast or can be sent to a specific remote radio. Moreover, the data can be sent in the packetized mode as an assigned data or as an immediate data. Please, refer to the ‘Appendix A’ for more details on the command/data sending in the packetized mode.

(1) Slave Data Packet Size in bytes (8-240):

This allows the user to assign the maximum number of data bytes in a packet, which can be sent within one slot. The minimum packet size is 8 and the maximum size is 240.

While TDMA timing is all based on a RF Data Rate of 3, the TDMA protocol can be run at a RF Data Rate of 2. When at 2, the packet sizes change from a maximum of 240 bytes down to a maximum of 180 bytes.

***** Note: Firmware versions up through 900 MHz 5.85, 2.4 GHz 1.85, and 225 MHz 1.07 only support Slave Data Packet sizes up to 239 bytes.

Note: The radio will break data up into packets by two methods, the first is a break in the data stream, and the second is at the set data packet size.

(2) Master Data Packet Size in bytes (8-240):

This allows the user to assign the maximum number of data bytes in a packet, which can be sent within one master slot.

While TDMA timing is all based on a RF Data Rate of 3, the TDMA protocol can be run at a RF Data Rate of 2. When at 2, the packet sizes change from a maximum of 240 bytes down to a maximum of 180 bytes.

Note: The radio will break data up into packets by two methods, the first is a break in the data stream, and the second is at the set data packet size.

(3) Number of Submasters (0-15):

This parameter assigns the number of submasters (master repeaters) within each master frame. The maximum number of submasters allowed in the network is fifteen. An entry of zero (0) means that there are no submasters in the network and the master will hear and talk to the slaves directly.

(4) Number of Slave Frames per Master Frame (1-15):

This assigns the number of slave frames that occur between a master frame. The minimum slave frame is one and the maximum slave frames allowed are fifteen.

(5) Number of Slave Repeaters per Frame (0-15):

This parameter assigns the number of repeaters within a slave frame. The maximum number of repeater allowed is fifteen. A setting of zero (0) means that there are no repeaters in the network and the master hears the slaves directly.

(6) Number of Master Frames in Epoch (1-255):

This assigns the number of master frames/frame castings that occurs within an epoch. This number can have a minimum number of one (1) or a maximum number of two hundred and fifty-five (255).

(7) Packet Delimiter Character (0-255):

This assigns a delimiter character in hexadecimal that is used to begin all packet transfers to and from the RS-232 port. This parameter is only valid in packetized mode. It is recommended that an ASCII character be used that is not commonly used. It is also suggested to have the same *Packet Delimiter character* on all of the radios in the system.

(8) System Slot Length (8-255):

This parameter is commonly used for elongating the frame casing timing for time sensitive applications. The default setting of eight (8) is the minimum amount of time necessary to process data before the beginning of the next frame casing.

Note: While many versions of firmware will allow the system slot to be set to less than 8, the radio will not work properly unless the system slot is set to at least 8.

(9) Edit Xmit/Receive Frames:

When this parameter is selected, the user will get a *Frame table* (see Figure 4). This frame table needs to be setup by the user with specific parameters, which is entry into the individual frame boxes. The specific parameters enter into the different frames will indicate whether the radio modem is to be a master, submaster, repeater, a slave or do nothing.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
30	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
40	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
50	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
60	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
70	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
80	00	00	00	00	00	00	00	**00**	00	00	00	00	00	00	00	00
90	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
A0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
B0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
C0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
D0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
E0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Enter Frame Number (esc returns to main menu)__

Each frame is represented as one entry in the table. To enter a value in a frame, you would first enter the first value of the line number on the left (row) and combine it with the number on the top (column). For example, the bold 00 value frame is accessible by typing - 87. The frame below if would be 97 and so on.

Figure 4 TDMA Frame Table

(A) Transparent Data Operation (0/1):

This parameter is valid for the transparent operation mode only. This parameter assigns the type of data for the radio. The type of data can be either assigned data or immediate. A value of zero (0) is for assigned data and a one (1) is for immediate. Assigned data is the most commonly used data type.

Assigned Data: The radio will transmit a packet on the first frame in the next frame casing that has a 20 (transmit) mark. If this radio does not have a 20 in it's frame table, then it will never transmit the data.

Immediate Data: The radio will randomly pick a frame from the next casing and transmit its data on that frame. The radio does not care if any other radios are set to transmit during this frame.

Note: Please note, that in the packetized mode selection between the assigned or immediate data can be done by selecting an appropriate '*Send data packet to a specific radio or broadcast'* command format only (refer to 'Appendix A" for more details and command format).

(B) Frame Table Reset on Disconnect (0/1):

This parameter controls whether or not a temporary frame table should be reset back to the original frame table if radio looses the synch to the master. A setting of zero (0) will not reset back to the original setup on disconnect. A setting of one (1) will reset the frame table to the original frame table when the radio disconnects.

Note: If the radio loses power, the temporary frame table will be lost due to being stored in non-volatile RAM. Next time radio turned on, the original frame table will be copied to the temporary frame table.

(C) Disconnect Message (0/1):

This parameter controls whether or not a disconnect message is transferred out of the RS-232 port whenever the radio disconnects. A setting of zero (0) gives no message on disconnect. A setting of a one (1) causes a message to be transferred out through the RS-232 port. The format of the message is defined by the *'Disconnect and Connect status message'* command (refer to the 'Appendix A' for more details).

The radio must be in packetized mode for this option to have any effect.

(D) End of Data Character (0-255):

This parameter assigns an ASCII character as the end of the data packet. The radio looks for this character in the data it receives. If the radio sees this end of data character, the data is parsed into two different packets and sent at different times.

Note: This ASCII character is in hexadecimal.

(E) Overwrite Assigned Buffer (0/1):

* This only applies to assigned buffer.

This parameter determines if the assigned buffer will be overwritten by data being received. The setting of a zero (0) does not allow the assign buffer to be overwritten. A setting of one (1) allows the assign buffer to be overwritten.

This parameter allows incoming data on the RS232 port to overwrite data already in the buffer. For GPS data and such where only the current data is of importance.

(F) Time Delay (0-238):

This parameter allows for a time delay to be inserted into the network. The time delay is necessary for links of greater than 20 miles and absolutely critical for links exceeding 80 miles. The value of the parameter should be incremented by 1 for every 10 miles over a 20-mile link. For example, a 50-mile link would require a setting of 3 in the Time Delay parameter.

Adds 2 clock ticks per slot, per increment. This setting effectively adds two bytes per slot per increment. Time for 2 bytes (138us) times the speed of light, gives a distance of 25.89 miles. Since this is round trip, dividing by 2 gives ~13 miles.

TDMA Related Parameters

Following is a list of user selectable options in other than TDMA menu, which define TDMA system operation and functionality.

Set Baud Rate Manu:
Radio Parameters Menu:

(3) RF Data Rate:

The “RF Data Rate” parameter should be set to 3. All factory testing, specs, and timing are based on an RF data rate of 3.

Note: A network will work at an RF data rate of 2, but the timing changes, and the maximum data packet size changes from 240 to approximately 180 bytes.

(8) Retry Timeout:

The value entered here is used to determine how long a radio can not hear the network before dropping the link to the network. This parameter is the number of master frames that can be missed before the radio drops the link. For example, when you leave the coverage area, and the radio can no longer hear the master (or a submaster), then it starts counting the master frames, or frame casings. When it reaches the number set here, the radio drops the link and tries to re-aquire the network.

The default is 255.

Note: This can cause delays of 1 minute and more easily depending upon your settings.

All of the setting in these menus define the radio functionality in the TDMA network in the same manner as they do so in other network types (Peer-to-Peer, Point-to-Point, or Point-to-Multipoint). Please, refer to the User Manual for more details.

Point-to-Multipoint Menu:

(1) Master Packet Repeat:

Setting this parameter to a number greater than zero (0) will allow each message (data packet or command) sent from the master, slave or slave/repeater radio in the TDMA network being repeated by sending radio an appropriate number of times. The message is repeated in the following assigned frames.

(6) Network ID:

This parameter adds exactly the same functionality to the TDMA network as it does to the Point-to-Multipoint network. In general, only radios with the same *Network ID* settings will be able to communicate with each other in the TDMA mode.

Note: The *NetworkID* contains 2 bytes, but in the TDMA system only the least significant byte (LSB) is used by the radio. Therefore, if the *NetworkID* is set to 269 (0x010D), for example, the radio can potentially communicate with another TDMA network, which has *NetworkID* set to 13 (0x000D).

(8) MultiMasterSynch:

In the TDMA mode this parameter allows synchronization between a few co-located TDMA masters. When *MultiMasterSync* is set to one (1), the co-located TDMA masters will be synchronized to each other in a manner similar to Point-to-Point or Point-to-Multipoint GrandMaster operation (refer to the 'FreeWave Grand Master Mode' document for more information). However, in the TDMA mode there are some additional RS232 lines wiring involved in order to assure a proper *MultiMasterSync* functionality. A complete setup procedure for TDMA *MultiMasterSynch* may be found in the "TDMA Networks with co-located masters. Setup instructions." (please contact FreeWave Technologies regarding this document).

(9) 1 PPS Enable/Delay:

Note: This feature is available for the radios with the serial numbers 571-0000 and above and the f/w version 5.59y and higher.

Note: This feature is only available in packetized mode.

Activating this parameter allows independent synchronization of all radios in a TDMA network to a time stamp generated by an external device and a 1 PPS

signal generated by a GPS receiver. In some applications it might be beneficial because in this case every radio in the network does not need to hear master's or submaster(s) transmissions. This simplifies the network topology design and allows for greater mobility of all radios within the network.

Specifications and Limitations:

(1) The radio must be supplied with a one PPS pulse on the DTR pin. The rising edge of the 1 PPS will be used as a one second timing reference and must have an accuracy of +/- 500 nsec.

(2) A new time stamp packet has been defined and must be sent to the radio within 200 msec after its corresponding 1 PPS. These only have to be sent during the radio acquisition phase but more than one may be needed until the radio has synched up.

Time Stamp format:

0xDD,0x00,0x04,0x00,0x45,0xMSB of TimeStamp,0xLSB of TimeStamp, SecondsPerEpoch

Field name	**Meaning/format**
0xDD	Delimiter byte (hex value)
0x04	Number of data bytes
0x45	Command code
0xMSB of TimeStamp and 0xLSB of TimeStamp	TimeStamp is a 16-bit number, which is the number of seconds within an arbitrarily defined GPS epoch. If the GPS epoch is defined as one hour, then the range of TimeStamp will be 0-3,600. A better epoch may be 7 hours giving a range from 0-25,200.
SecondsPerEpoch	SecondsPerEpoch is defined as the number of seconds for a TDMA Epoch. The minimum allowed is 1. Any other value must divide into the defined GPS Epoch. If this Epoch length is 3600 seconds (1 HR) then the allowed values of SecondsPerEpoch is 1,2,3,4,5,6,8,9,10,12,15,etc An epoch length of 7 hrs will allow a value of 7 for SecondsPerEpoch to be used.

(3) The TDMA parameters MUST be set up so that a TDMA Epoch lasts exactly the number of seconds in SecondsPerEpoch. The SystemSlot parameter is useful to fine-tune the Epoch length.

(4) A slave radio will try to synchronize through the RF while waiting for the TimeStamp packet.

(5) When synched up, all radios must continue to get the 1 PPS. If a PPS is missed the radio will return to acquisition mode.

Programming the Frame Table

The frame table is used to specify the function of the radio during each frame. The radio can be programmed to transmit, receive, repeat or do nothing. The Frame Table is accessible through the TDMA parameter table. By selecting item nine (9), the frame table will display (see Figure 4). Each box in the frame table is a frame. As you may recall, a frame is made up of 1 to 16 slots. Refer to Figure 5 for a visual perception.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
30	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
40	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
50	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

1 to 16 slots equals a frame

0 15	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

Figure 5 Slots in the Frame Table

Frame location 0x04h has been expanded to give a visual representation of the slots contained in a frame.

From what is seen in Figure 5, the entries in the frame table all have a value of “00”. Unless we change these values, the radio at this time is programmed to do nothing. The values for programming the frame table for the radio modem consist of two values, which are referred to as an upper nibble and a lower nibble settings. The upper nibble (Figure 6) sets the function of the radio within the frame and the lower nibble sets the slot position for that function to happen.

Upper nibble sets the radio’s function and the lower nibble specifies what slot the function will occur within a specified frame.

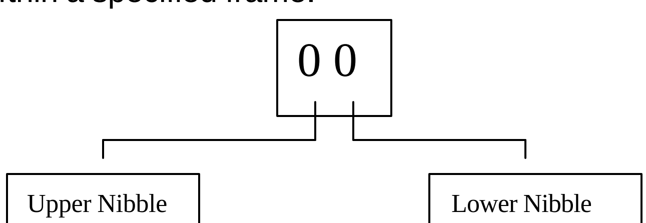


Figure 6 Frame Nibble Explanation

Note: The frame table is laid out in a square fashion because it displays better on the screen. The frame table in time is sequential:

00, 01, 02, … 0E, 0F, 10, 11, … 1F, 20, 21 … etc.

Upper Nibble Settings

(0) A setting of zero (0) assigns the radio to be idle during this frame. It is effectively doing nothing but listening in the background. The lower nibble is irrelevant and is ignored. However, any RF commands or data directed to that radio, from a radio in packetized mode, is received and transferred out the RS-232 output. Data broadcast to all is ignored and data received from transparent mode radios is ignored.

(1) When this is set to one (1) the radio will listen for any radios that transmit within that particular frame. The radio will receive the data and send this data to the RS-232 port. However, if the data is from a packetized radio and the data is addressed to another radio, the data is not sent to the RS-232 port.

(2) A setting of two (2) in a master radio or a slave radio will transmit any data received on the RS-232 port during the assigned frame as long as the lower nibble is set to zero (0). If the radio is to be a submaster (master repeater) or a repeater (slave repeater) a setting of two (2) in the upper nibble must be accompanied with a lower nibble pointing to a slot other than slot zero (0). The radio, which is set to be a repeater or submaster, does not output the data to the serial port.

(3) A setting of three (3) in the upper nibble will repeat what radio hears on slot zero. The lower nibble determines what slot the message will be repeated on. This setting of three (3) also allows data, which radio received, to be sent out the RS-232 port. This setting is useful if you need a slave to act as a repeater.

Lower Nibble Settings

The lower nibble sets the slot position within the frame, which a radio will perform a specific function. The upper nibble is the main determinant in what the radio will actually do in a particular frame. The following gives the rules for the lower nibble settings:

(0) A zero (0) nibble setting is only allowed with an upper nibble setting of a zero (0), one (1), or two (2). The zero (0) nibble varies in meaning depending on the upper nibble setting. See Table 2 for different meanings.

Meanings of Different Frame Settings

This setting tells the radio during this frame to do nothing, however if the radio receives a packetized command from the master the radio will send it out the RS-232 port.

10	This setting tells the radio during this frame to listen and send whatever it hears to the RS-232 port as long as this data is not addressed to another radio using packetized mode. A radio will listen on all slots, until it hears a valid packet. Setting to 11, 12, … has no effect, and is not recommended.
20	This setting tells the radio during this frame to transmit data which was received from the RS-232 port and transmit this data on slot zero (0) of that frame.
2x	The x – value refers to the slot number in which data or command is repeated which was heard the slot before from a transmitting master, slave or another repeater. The data, which is heard and repeated, is not sent to the RS-232 port.
3x	The x – value refers to the slot number in which data or command is repeated which was heard the slot before from a transmitting master, slave or another repeater. The data, which is heard and repeated, is sent to the RS-232 port. This setting is useful if a slave is needed to be used as a submaster or a repeater.

Table 2 Frame Table Settings

(1-15) A lower nibble setting of one (1) to fifteen (15) refers to the slot in which a process takes place. A setting greater then zero in the lower nibble is used for radios which have been designated to repeat data that it hears.

Note: The entries in the frame table are to be entered in hexadecimal. Therefore, the reference made in the lower nibble section referencing the lower nibble (1-15) should have entries in the frame table consisting of 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, or F hexadecimal numbers**.**

Note: A repeater or submaster will repeat the data from the first slot that that radio hears prior to its assigned transmit slot. For example, if you have a master with two submasters through which the data must flow consecutively, the first submaster will repeat on slot 1 what it heard in slot 0. The second submaster

who can not hear the master directly, will miss the transmission on slot 0, but will hear the transmission on slot 1 and will repeat that on slot 2.

However, if we have a system where both submasters can hear the master, then submaster 1 will repeat what it hears on slot 0 in slot 1. Submaster 2 will listen on slot 0, and if it hears the master's transmission correctly, then it will repeat this message on slot 2. If it does not receive the master's transmission properly, then it will listen on slot 1 for the repeated message. If it receives this message correctly, it will repeat this message on slot 2.

Master Frame (Frame 00/0)

As you recall from the definition section, the master and submaster radios only use Master Frame. The master and submaster radios only use the very first frame of the frame table (refer to Figure 7). The actual location in the frame table is 00/0.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	**00**	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

The master frame. Only the master radio and the submaster are allowed to use this frame.

The radio assigned to transmit in this frame is always the master. Only one master is allowed in a network. The master frame is the heartbeat of the network. It transmits synchronization and timing data to every radio within the network either directly or indirectly through submasters.

Figure 7 Master Frame

Frame 00/0 (the first frame in the frame table, Figure 7) is special and represents the action of the radio during all master frames. No other frame can be set as a master frame. All master frames must be identical unlike slave frames that can change after each master frame within an epoch. All successive master frames as specified by the parameter "Master Frames per Epoch" DO NOT show up in the frame table, they have the same settings as the 00/0 frame. In other words, the master frame shows up only once in the frame table at 00/0, but in time there is one master frame per frame casing.

Master's Frame Table:

	0	1	2		3	4	5	6
00	**20**	10	10	*20*	10	10	00	00

Slave 1 Frame Table

	0	1	2		3	4	5	6
00	**21**	20	10	*21*	20	10	00	00

Slave 2 Frame Table

	0	1	2		3	4	5	6
00	**10**	10	20	*10*	10	20	00	00

2 Slave Frames per Master Frame
2 Master Frames per Epoch.

Implicit master frame that is exactly the same as frame 00/0.

Figure 8 Implicit Master Frames

Operation Modes

There are two modes of operation in TDMA, Transparent Mode and Packetized Mode. When the radio operates in transparent mode, all characters transferred to and from the RS-232 port are treated as data only. No additional characters or control commands are included with the data. Control of the packet size is not necessary because the radio will automatically parse the data into packets before it is transmitted. Packetized mode does require control of the packet size. The data that is received from the RS-232 must contain a header packet, which contains a delimiter, 3-byte address, byte count and the data. This header packet size can vary depending on the type of action is required.

The CTS (clear to send) line can be used to synchronize data transfer to the radio over the RS-232 port. It will remain asserted (high) until the beginning of a scheduled transmitting slot. At the beginning of the slot, the CTS line is de-asserted (low), and remains de-asserted for the duration of the slot. It is asserted (high) at the end of the slot. To prevent fragmentation of data packets, it is recommended to trigger the data transfer to the modem on the rising edge of the CTS. The CTS line will de-assert when the internal 1KByte buffer gets full. The CTS line will stay de-asserted until the internal buffer starts to empty.

The CD (carrier detect) line is de-asserted when the radio has power. Once the slave syncs, the CD light on the radio modem turns solid green. For all radios other than the master, the CD light will stay green as long as the slave radios are synchronized with the network.

Table 3 CD Light and Line States

CD Light		
	Green	In sync with network
	Red	Out of sync with network
CD Line		
	Asserted	Normally
	De-Asserted	When radio is receiving data from the network.

Operation in Transparent Mode

There are two different data types, immediate and assigned. If the data type is immediate, the radio will transmit one time only on a random selected slave frame after the next frame casing. If the data type is assigned data, the radio will transmit the

message in its buffer during the assigned slot. New data received from the RS-232 port will delete any previous data in the radios RS-232 buffer.

Operation in Packetized Mode

All data sent in and out of the RS-232 port begins with a header packet. All data packets must be less than or equal to the maximum data size set up initially in the TDMA setup menu for “Slave Data Packet Size in Bytes” and “Master Data Size in Bytes”. The header packet is not considered part of the data. See Table 3 for a listing of all of the packetized commands.

Note: All dynamic allocations of frame function are stored in non-volatile RAM. Any loss of power will cause all changes to reset back to the original setup parameters set by the user.

Table 4 Packetized Mode Commands

Commands executed on the local radio only		
	Command code	**Action**
1	0x30	Tell local radio to return its ID number.
2	0x31	EEPROM individual address write and read command.
3	0x32	RAM individual address write and read command.
4	0x44	Disconnect and Connect status message: The TDMA parameter ‘Disconnect Message’ needs to be set for this feature.
5	0x53	Tell local radio to go into the setup mode.
6	0x60	Bulk load of TDMA Settings, TDMA Frame Table and Frequency table.
7	0x61	Bulk load of frame table.
8	0x62	Tell local radio to respond with its signal quality packet.
9	0x63	Get radio’s firmware version.
Commands executed on the remote radio only		
	Command code	**Action**
10	0x37	Tell remote radio to respond with its signal quality packet on specified frame.
11	0x42	Tell remote radio to transmit a status packet on specified frame.
12	0x46	Special Data Packet command: sends data to a specific radio or radios on a specified frame.
13	0x48	“Who’s out there” command.
14	0x4C	Tell remote radio to listen to all packets on specified frame.
15	0x4E	Tell remote radio to be idle on specified frame.
16	0x52	Tell remote radio to become a repeater/submaster.
17	0x54	Tell remote radio to transmit on specified frame.
18	0x6D	Gather routing information from source radio to destination radio.
19	0xDD,0x##0x##0x##,0x00+data packet length,####(data)	Send data packet to a specified radio or broadcast.

Note: Refer to the Appendix A for detailed commands descriptions.

There are two types of data messages, assigned and immediate. If the address field of the message is set to the sending radio's address, the message is called an *assigned message*. An assigned message is stored by the radio until a new assigned message is received on its serial port. An assigned message is then broadcast by the radio during the frame that is designated for transmitting. However, if the radio has other messages to broadcast, those messages are transmitted instead.

The second type of data message is an *immediate message*. An immediate message is broadcast in a frame selected by the radio. If the radio is a master radio, the data is broadcast in the next master frame slot. If the radio is a slave radio the data is broadcast on a randomly selected slave frame between the next slave frames.

Network Acquisition

A radio operating in TDMA mode will acquire the network the same way as in a standard point to multipoint mode. If the radio is not the master the radio will search for any master or submaster which is in its call book. If the call book is not used the Network Id must be used. The radios in the network must have the same setup, as far as the “Radio Transmission Parameters” and “Multipoint Parameters”. There are some parameters, which are not used by the TDMA mode. In the “Radio Transmission Parameters”, Max Packet size and Min Packet size are not used. In the “Multipoint Parameters”, Number of Repeaters, Max Slave Retry, Retry Odds, DTR connect, MultiMasterSync and 1PPS are not used. Even though the items listed are not used, it is good practice to ensure that all radios in the network have the same setting.

Epoch Timing

The TDMA protocol allocates specific and fixed time slots to radios within the network. The FreeWave “Time Division Multiple Access” (TDMA) protocol is basically for real time data collection. Table 4 gives the items and a description of each, that are used to calculate the transmission time of one epoch.

Transmission Timing

Items	Description
69.444 µs	the time it takes to transmit one (1) byte of data.
2.917 ms	The overhead and header packet transmission time.
1 System slot time	(Slot length + 4) * 69.444 µs
1 Slave slot time	((Slave Packet Size + 2 * (Time Delay))* 69.444µs) + 2.917 ms
1 Master slot time	((Master Packet Size + 2 * (Time Delay))* 69.444µs) +2.917ms
1 Slave frame time	(1 Slave slot time) * (1 + Number of repeaters)
1 Master frame time	(1 Master slot time) * (1 + number of submasters)
Time for all Slaves	(1 Slave frame time) * (number of slave frames per master frame) in 1 frame casing
1 frame casing time	(1 Master frame time) + (Time for all Slaves In 1 frame casing) + (System slot time)
Time for 1 epoch	(1 frame casing time) * (Number of master frames in an Epoch)

Figure 9 Epoch Time Calculations

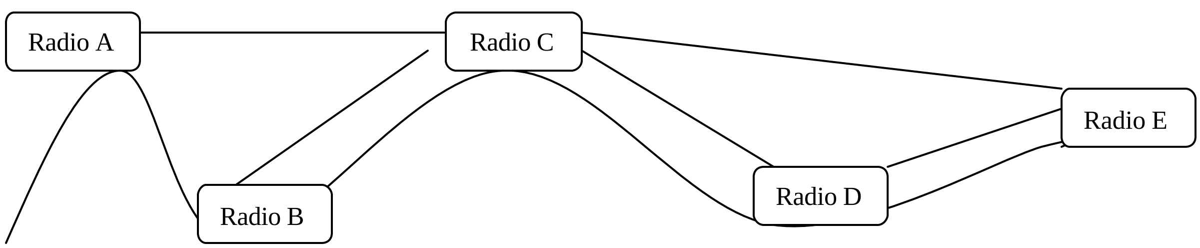
Examples of TDMA Networks

Example 1

This section will walk through the process of setting up a TDMA network. Hopefully, by the end of this section all questions will by eliminated and you will be ready to setup your own TDMA network.

Step One

We have determined that five radios are needed for collecting real time data. Figure 8 gives an example of the geographical location of our five radios.



The lines in between radios indicate that these radios can hear each other. So, in this figure Radio A can hear Radio C, Radio C hears Radio B, Radio D, and Radio E, Radio D hears Radio C and Radio E, and Radio E hears Radio D and Radio C.

Figure 10 Example Network 1

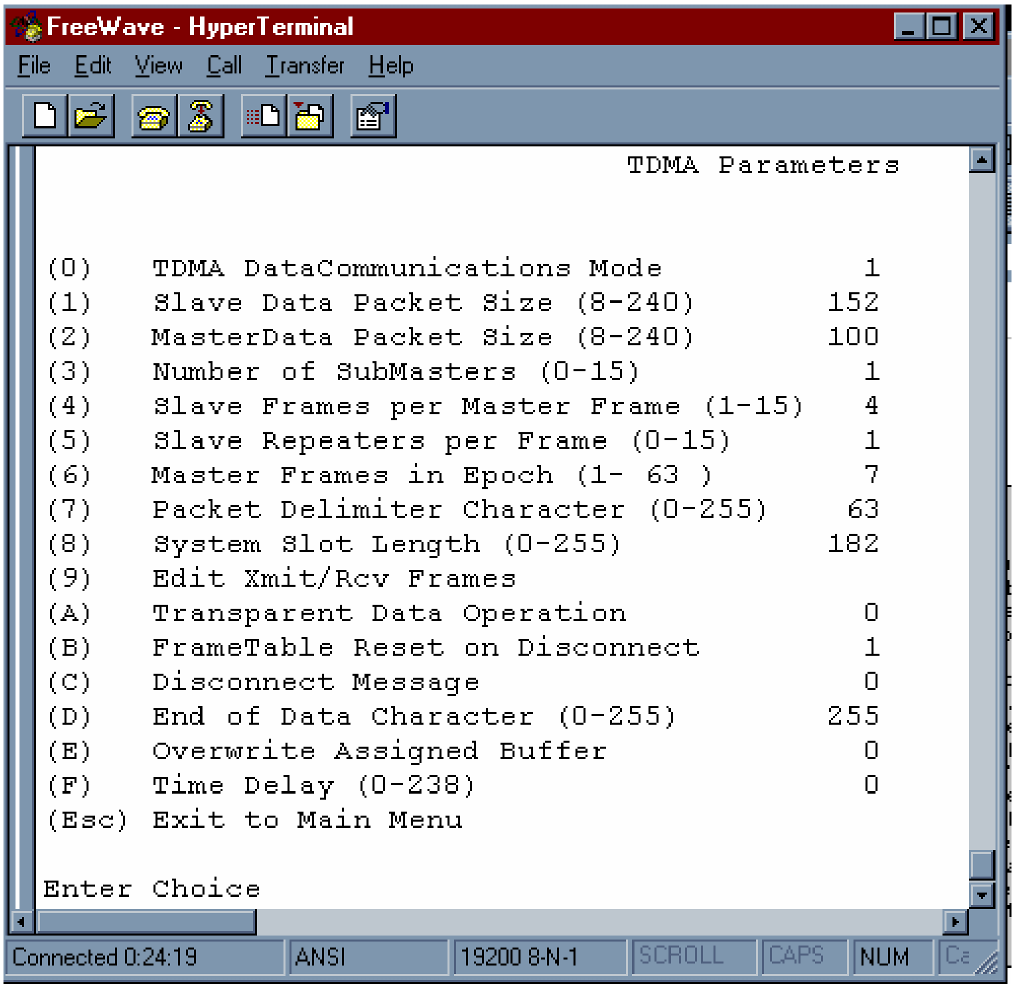
Referring to Figure 8, Radio A is going to be our Master station, Radio C is going be setup as a repeater station and have a GPS receiver connected to it. Radios B, D and E are going to have GPS receivers connected to them and will be setup as Slave stations only.

Step 2

The next step involves the TDMA Parameter table. Figure 9 shows a default table. The first parameter we need to determine is the *TDMA Data Communication Mode*. This parameter can be select as a packetized or transparent mode. The slave radios are

connected to GPS receivers, these devices cannot build packetized data. Therefore, these radios will be set up in transparent mode. The master station can be setup in transparent or packetized mode. But we want the ability to use some of the packetized commands, so the master station is going to be setup in packetized mode. The *TDMA Data Communication Mode* setting for our master station will have a setting of one (1) and the repeater and the slave radios will have a setting of zero (0).

Table 5 Example 1 Settings



Step 3

The next parameters consist of the *Slave Data Packet Size* and the *Master Data Packet Size*. This parameter value can be any number between 8 and 240. The *Slave Data Packet Size* is going to be set to 152 data bytes and the *Master Data Packet Size* is going to be set to 100 bytes. Referring back to the section Epoch Timing, we know that it takes 69.444µs to send one byte of data. Therefore, 152 bytes of data to be sent within one (1) slave frame slot would take

(slave packet size * 69.444µs) + 2.917ms = (152 * 69.444µs) +2.917ms=13.472488ms.

A master slot would take:

(master packet size * 69.444µs) + 2.917ms = (100 * 69.444µs) +2.917ms=9.8614ms.

Step 4

The *Number of SubMasters* and the *Number of Slave Repeaters per Frame* are the next parameters to consider. From the description above we know that one of the radios (Radio C) in our example is going to be a repeater. The radio, which repeats the master's signal is labeled as a *SubMaster*. In our case, Radio C will be our only submaster in the system. Due to the fact that signals from radios B, D and E cannot be heard directly by the master, the number of repeaters in the system would only be one (1). Radio C can hear and be heard by the master and the slaves. Therefore, the *Number of SubMasters* should be set to one (1) and the *Number of Slave Repeater per Frame* should be set to one (1) as well.

Step 5

Number of Slave Frames per Master Frame is the next parameter to set. Referring back to our example, we know that radios B, C, D, and E have GPS receivers connected to them. We also know that Radio C is going to be a SubMaster and a Repeater for the network. Although Radio C has been designated as a SubMaster and a Repeater, it will also operate as a slave. Therefore, the number of slaves in the system per master frame will be four (4).

Step 6

The next parameter we needed to set is *Number of Master Frames in Epoch*. As you recall, an Epoch is a period of time that combines 1 or more frame casings. In our case, we have four (4) slaves and one master in our one (1) frame casing. Therefore, theoretically we can setup the *Number of Master Frames in Epoch* to be up to 63:

255/(number of slaves) = (255 / 4) = 63.

Due to simplicity of the network that we are trying to configure, it makes sense to keep the *Number of Master Frames in Epoch* at one (1). In some applications the system may require more than 1 frame casing per epoch. In this case one would need to relate to the system slot in helping to tune network timing.

Step 7

The *System Slot Length* parameter is used to elongate the frame casing timing for time sensitive applications. Since we have determined all the necessary parameters for our network, we can now determine the amount of time it takes to receive our data in an epoch. The following is the calculations of what time it takes to transfer our real time data:

1 Slave slot time = (152)*(69.444µs) + 2.917ms = 13.472488ms;

1 Master slot time = (100)*(69.444µs) + 2.917ms = 9.8614ms;

1 Slave frame time = (13.472488ms) * (1 + Number of repeaters) = (13.472488ms)*(2) = 26.9450ms;

1 Master frame time = (9.8614ms)*(1 + Number of submasters) = (9.8614ms)*(2) = 19.7228ms;

Time for all Slaves in 1 frame casing = (26.9450ms) * (Number of slave frames per master frame) =
= (26.9450ms) * 4 = 107.7799ms.

Without the System Slot Length, the epoch time will be

1 frame casing time $_{\text{without system slot}}$ = (19.7228ms) + (107.7799ms) = 127.5027 ms.

From our experience in some applications it is beneficial to have a TDMA radio network synchronized to the GPS data dumping timing. Let's consider a case when slave radios generate GPS data every 150 msec.

Going back to our '1 frame casing time without system slot' calculations, it is obvious that in order to synchronize the radio system to the GPS timing the TDMA system epoch duration has to be increased by about 22.5 msec or so. As mentioned before, the system slot may help us to do this. The following shows the calculations for determining the system slot length:

150ms = (1 frame casing time $_{\text{without system slot}}$) + (System slot time);

150ms = (127.5027ms) + (System slot time);

System slot time = 150ms - 127.5027ms = 22.4973ms.

Replacing 'System slot time' with '(System Slot length + 4) * 69.444µs', we get

(System Slot length + 4) * 69.444µs = 22.4973ms;

System Slot length = (22.4973ms – 0.277776ms) / 69.444µs;

System Slot length = 31.9982.

Therefore, the *System Slot Length* needs to be 32 for an epoch timing being 150 msec.

Step 8

The next parameters, *Packet Delimiter Character*, *Transparent Operation*, *Frame Table Reset on Disconnect*, *Disconnect Message*, *End of Data Character*, and *Overwrite Assign* all need to be set.

The *Packet Delimiter Character* can range from '0' to '255'. It does not make any difference on the functionality of the radio in general. This parameter does not make any difference on the functionality of the radio in general, but it is very important for the packetized mode operation. We will set it arbitrarily to '99' (0x63 or 'c').

The *Transparent Operation* is going to be set to zero (0) for data to be assigned. Setting this parameter to assigned, means the data is sent during the assigned transmit frame.

The next parameter *Frame Table Reset on Disconnect* refers to the original frame table setup. Let's say, during the operation of our network we decided to change the transfer frame of one of our slave to another frame by using local or remote commands. By setting *Frame Table Reset on Disconnect* to one (1), the table will be restored to the original setting if the radio disconnects from hearing the master directly or indirectly.

The *End of Data Character* in our example is set to 255, which means there is no end of data character.

The next parameter, which needs to be set is *Overwrite Assign Buffer*. If this parameter is set to zero (0) and our timing is off, our data could be overwritten before we send the data. For our example, this setting is set to one (1). Therefore, our data will not be overwritten until we have transferred it.

Step 9

The last parameter to be set is *Edit Xmit/Receive Frames*. For our example, Radio A is the master station, Radio B, C, D, and E are slaves and Radio B is acting as a submaster and repeater for the network.

Figure 10 shows a listing of the master table, slave table and the slave – repeater – submaster tables.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	**20**	10	10	10	10	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

a) Master stations radio frame table setup. Master slot 00/0.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	31	20	21	21	21	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

b) Submaster, Repeater and Slave – refer to Radio C

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	10	00	20	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

c) Slave, refer to Radio B

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	10	00	00	20	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

d) Slave, refer to Radio D

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	10	00	00	00	20	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

e) Slave, Refer to Radio E

Figure 11 Example 1 Frame Table

In a) the master frame table (00/0) is set to 20, the other 4 frames are set to 10. This assures the radio will hear what is broadcasted in these frames and will be sent to the serial port. In b), shows the frame table of Radio C. In the frame 0 slot 1 (00/1) the radio retransmits what it heard in slot 0 and outputs it to the serial port. In frame 00/1 the

radio is a slave and should send its data in this frame. The frames 00/2 – 00/4 acts as repeater frames and the data which it hears is repeated on slot 1. Since the upper nibble is a 2, the data is not sent out to the serial port. In c) the slave is told to listen and output what it hears on 00/0, do nothing for frame 00/1, 00/3 and 00/4. In frame 00/2 the radio is to transmit the data. In d) the slave is told to listen and send what it hears to the serial port in frame 00/0. For frames 00/1, 00/2, and 00/4 the radio is told to do nothing. Frame 00/3 the radio is told to transmit its data. In e) the radio is told to listen and send what it hears on frame 00/0 to it serial port, not to do anything for frames 00/1, 00/2, and 00/3 and to transmit its data on frame 00/4.

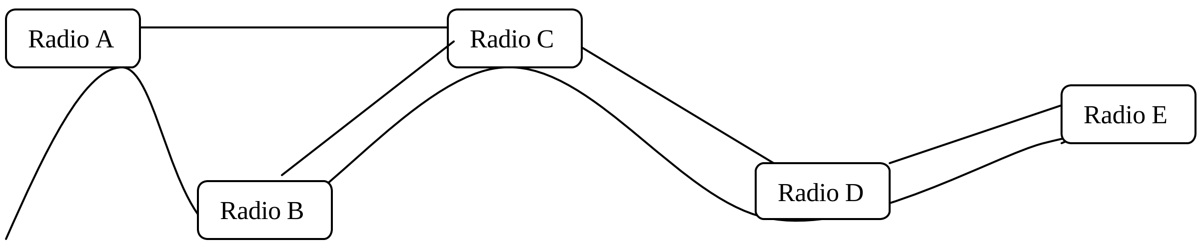
Step 10

The radios have now been setup and are ready to go. Make sure that the other parameters are setup correctly. Now the system is ready to go, make sure the radios have the same *Network ID*. If you are not using the *Network ID* then it is imperative that the Call Books are properly programmed.

Example 2

Note: The purpose of this example is to show how the frame table from the Example 1 will need to be changed if the network topology described above will be slightly different. Therefore, in this example we will not review all of the steps taken in the Example 1 and will concentrate on the changes in the frame table settings only.

Consider the same network topology as in the Example 1, but the Radio E can not hear the Radio C. Figure 11 below reflects this change.



The lines in between each pair of radios indicate that these radios can hear each other. So, in this figure Radio A can hear Radio C, Radio C hears Radio B, and Radio D, Radio D hears Radio C and Radio E, and Radio E hears Radio D.

Figure 12 Example 2

Referring to Figure 11, Radio D will need to be programmed now to function as a submaster during the master frame, as a repeater during the frame assigned for Radio E transmission, and as a slave during its own dedicated frame. Therefore, the *Number of Submasters* in this case should be set to 2 (Radio C and Radio D) and the *Slave Repeaters per Frame* will also need to be set to 2 (Radio C and Radio D).

Skipping Steps 1 through 8 from the previous Example, let's see how the frame tables will need to be changed to accommodate the network topology difference.

Following is analysis of the given frame tables for each radio and the ways of their improvement/customization.

Figure 13 Example 2 Frame Table

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	**20**	10	10	10	10	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

a) Master stations radio frame table setup. Master slot 00/0.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	31	20	22	22	22	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

b) Submaster, Repeater and Slave (refer to Radio C).

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	10	00	20	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

c) Slave (refer to Radio B).

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	32	00	00	20	21	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

d) Submaster, Repeater and Slave (refer to Radio D).

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	10	00	00	00	20	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

e) Slave (refer to Radio E).

Radio A. On the Master radio the master frame (frame 00) is set to '20', the other four frames are set to '10'. This assures that the Radio A will listen to all of the remote radios transmissions.

Improvement note: Due to the fact that the master radio can hear only Radio C, it is possible to setup the master's frame table with '20' in the frame 00, '10' in the frame 01 and '00' in the rest of the frames. As a matter of fact, this frame table configuration will allow a slight reduction in master radio power consumption

because during the frames 02 through 04 master will be idle instead of being in the receive mode.

Radio B. There are no changes being made to the frame table of this radio.

Customization note: The contents of Radio B frame 03 and frame 04 may be changed from '00' to '10', which will allow Radio B to listen to all of the transmissions from the Radio D and Radio E.

Radio C. During frame 00 slot 1 (00/1) Radios C re-transmits what it heard on slot 0 and outputs it to the serial port. The frame 01/0 is assigned for the Radio C transmission (value '20' in it). During the frames 00/2 – 00/4 Radio C acts as repeater, which is indicated by the value of '22' in them. So, during the slot 2 within the frames 01…04 Radio C will re-transmit what it heard on slot 0 or slot 1 within the same frame.

Customization note: The frame 02 and frame 03 contents on Radio C may be changed from '22' to '21'. It will not effect the functionality of the system, but it will allow the data from Radio B and Radio D to be re-transmitted by the Radio C one slot sooner. This may or may not have effect on the overall system performance, but could be useful in some applications. FreeWave Technologies, from the frame table consistency standpoint, recommends keeping frame 02 and frame 03 contents at '22'.

Radio D. During the frame 00 slot 02 this radio re-transmits what it heard on slot 0 or slot 1 within the same frame. In other words, during the frame 00 Radio D acts as a submaster.

During the frames 01 and 02 this radio is idle. Frame 03 is assigned for its transmission and during the frame 04 slot 01 it re-transmits what it heard on frame 04 slot 00 (Radio E transmission).

Warning note: Please note that if Radio C will have '32' in its frame 00 and Radio D will have '31' in its frame 00, the system will not function because Radio D will not be able to re-transmit direct master's transmissions. So, the Radio D and Radio E will not be able to synch up to the master in this case.

Changing the contents of frame 04 on Radio C from '22' to '21' and at the same time changing the contents of frame 04 on Radio D from '21' to '22' will cause Radio E messages being delivered only to Radio D.

Radio E. There are no changes being done to the frame table of this radio.

Customization note: The flexibility of the frame table and TDMA system features allow the user to add one or more ‘listeners’ to the system. ‘Listeners’ will not need to have a dedicated frame assigned to them and will simply act as control points. If ‘listener’ will be installed somewhere where it can hear transmission from Radio C, then setting its frame table with all ‘10’ in frames 00 through 04 will allow it to hear all of the transmissions between the radios in the system without interfering with them.

Example 3

Note: The purpose of this example is to show how to add one more frame casing to the system given in Example 1 and what effect it will have on the system performances.

From the 1 frame casing time $_{\text{without system slot}}$ calculations in Example 1, we know that the duration of epoch:

Time for 1 epoch = 1 frame casing time $_{\text{without system slot}}$ + system slot time.

If the *System Slot Length* is set to eight (8), then the system slot time will be

1 System slot time = (System Slot Length + 4) * 69.444µs = 833.328µs.

Therefore, the epoch time (1 frame casing per epoch) will be

Time for 1 epoch = 127.5027ms + 833.328µs = 128.336ms.

So, the master in Example 1 can send up to 100 bytes (refer to *Master Data Packet Size* settings*)* every 128.336ms.

The number of slaves we currently have is four (4). For explanation purposes we can divide these slaves into two 'groups' - two slaves per 'group'. Each 'group' will need to have its own master frame with the system slot before it. Therefore, the following changes should be made in the TDMA Parameters menu:

- *Master Data Packet Size* set to 50 (instead of 100);
- *Master Frames in Epoch* set to 2 (instead of 1);
- *Slave Frames per Master Frame* set to 2 (instead of 1).

Please note that the frame table on all of the radios does not need to be changed.

To find what effect on the radio performances these changes will have, let's make timing calculations similar to the ones given in the Example 1.

1 Slave slot time = (152)*(69.444µs) + 2.917ms = 13.472488ms;

1 Master slot time = (50)*(69.444µs) + 2.917ms = 6.3892ms;

1 Slave frame time = (13.472488ms) * (1 + Number of repeaters) = (13.472488ms)*(2) = 26.9450ms;

1 Master frame time = (6.8614ms)*(1 + Number of submasters) = (6.3892ms)*(2) = 12.7784ms;

Time for all Slaves in 1 frame casing = (26.945ms) * (Number of slave frames per master frame) =
= (26.945ms) * 2 = 53.89ms.

An epoch time will be:

1 frame casing time $_{\text{without system slot}}$ = (12.7784ms) + (53.89ms) = 66.6684ms;

1 frame casing time with the system slot = 66.6684ms + 0.833328ms = 67.5017ms;

Epoch time = (1 frame casing time) * (Number of master frames in epoch) = 67.5017 ms * 2 =
= 135.0035ms.

Comparing to what we had in the Example 1

Epoch time from the Example 3/Epoch time from the Example 1 = (135.0035ms/128.336ms) = 1.052,

The new epoch time is about 5% longer than what we had before. Obviously, this increment is due to the fact that there is one extra System Slot and one extra header in the beginning of the master frame. But, in some cases it might be beneficial.

Following table shows master transmission time calculations (10 seconds period of time was used for comparison).

Table 6 Example 3 Timing Comparison

Parameter	Example 1 system, ms	Example 3 system, ms	Notes
1 Master Slot time	9.6814	6.3892	
1 Master Frame time	19.7228	12.7784	
Total master frame time per epoch	19.7228	25.5568	
Epoch time	128.336	135.0035	
Number of epochs within 10 sec. period	78	74	
Total Master transmission time in 10sec. period	1,538.4	1,891.2	
Timing comparison of the original system configuration (Example 1) and after an additional master frame has been added to the epoch with no other settings changed (Example 3).			

So, adding one extra master frame per epoch to our original setup increases master transmission time by about 23% if the rest of system parameters have not being changed. This means that the remote radios will have 23% higher chance to synchronize to the master than before for the price of about 5% system's throughput degradation and some minimal power consumption increase on the master radio.

Note: The data in the Table 5 was calculated based on assumption that the master in both examples transmits continuos data. If the master will transmit no data but the header packets only, the difference between Example 1 and Example 3 configurations will be even higher.

In conclusion, adding an extra master frame per epoch might be beneficial in applications where primary synchronization between the radios is an issue. But, to

achieve the highest slave-to-master data throughput, the number of master frames per epoch should be as low as possible.

Example 4

Note: The purpose of this example is to show how to set up the radios when they are setup to have more than one Master Frame per Epoch.

For this example, the radios were set up with the following parameters.

Slave Frames per Master Frame	5
Master Frames in Epoch	10

The frame table is assigned such that 00/0 is the master frame, 00/1 is slave 1, 00/2 is slave 2, continuing to 30/2 being slave 50 (32h = 50d) as shown in table 6. When set up this way, the sequence will be the system slot, the master frame, and then five slave frames. Since the Master Frames in Epoch is greater than one, it will keep its place, and then transmit the next 5 slave frames the next time. The actual transmission sequence of the system is shown in table 9.

Table 7 Example 4 Radio Frames

Showing how the frames are assigned to different radios.																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	Master	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
10	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31
20	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45	S46	S47
30	S48	S49	S50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

The frame table of the master radio should be set to transmit in frame 00/0, and listen in the other frames that are used. This is shown in table 7.

Table 8 Example 4 Master Frame Table

The frame table of the master radio, showing in bold the frame where it transmits. Frames 30/3 through 30/F are unused.																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	**20**	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
30	10	10	10	00	00	00	00	00	00	00	00	00	00	00	00	00

Each individual radio should be set to listen to the master (frame 00/0), and transmit on its specified frame. The frame table for slave 38 is shown in table 8.

Table 9 Example 4 Slave 38 Frame Table

The frame table of slave 38, showing in bold the frame where it transmits and listens. Listens on frame 00/0 and transmits on frame 20/6.																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00	**10**	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
10	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
20	00	00	00	00	00	00	**20**	00	00	00	00	00	00	00	00	00
30	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Table 10 Example 4 Actual Transmission

The actual transmission sequence of the system.						
SS	Master	Slave 01	Slave 02	Slave 03	Slave 04	Slave 05
SS	Master	Slave 06	Slave 07	Slave 08	Slave 09	Slave 10
SS	Master	Slave 11	Slave 12	Slave 13	Slave 14	Slave 15
SS	Master	Slave 16	Slave 17	Slave18	Slave 19	Slave 20
SS	Master	Slave 21	Slave 22	Slave 23	Slave 24	Slave 25
SS	Master	Slave 26	Slave 27	Slave 28	Slave 29	Slave 30
SS	Master	Slave 31	Slave 32	Slave 33	Slave 34	Slave 35
SS	Master	Slave 36	Slave 37	Slave 38	Slave 39	Slave 40
SS	Master	Slave 41	Slave 42	Slave 43	Slave 44	Slave 45
SS	Master	Slave 46	Slave 47	Slave 48	Slave 49	Slave 50

Appendix A – Packetized Commands

Description

General Rules/Definitions applied to all of the commands and used in this document.

There are two command types: local and remote.
The remote command is addressed to one or more remote radios.
The local command is addressed to a local radio. If the local radio heard the command, it will evaluate it and in some cases respond back to the RS232 port with a string indicating that the command took effect.
Any data or command in the packetized mode must begin with a 'Delimiter'. The 'Delimiter' is a byte of data specified in the *'TDMA Parameters'* Menu under *'Packet Delimiter Character'*. It could be anything from 0 to 255. Please, note that '0' and '255' are valid entries. 'Delimiter' in the command must match *'Packet Delimiter Character'* settings. Otherwise the command will be discarded without evaluation.
The command must contain at least 5 bytes. The first four bytes of any command should not be included in the *Command length* calculations. For example, the length of the command ***0xDD,0x00,0x02,0x00,0x44,0x00*** is 2 bytes.
The command string must not include <LF>, <CR> or any other symbols unless specified in the command format. Comas (",") listed in the command format only for easier-to-read purpose. Comas must not be included when issuing the command to the radio.
Replies returned back by the radio do not include <LF>, <CR> or any other symbols unless specified in the return string format. Comas (",") listed in the radio replies formats are for easier-to-read purpose only and will not be a part of an actual radio's reply.
In this document 'Yes' under the column labeled 'User adjustable' means that the corresponding byte within the command may need some user adjustments. Respectively, 'No' under the same column means that this value should stay the same as specified in the command format or can not be adjusted because it is a part of radio's response.
For example, the 'Delimiter' for all commands will need to be chosen by the user according to *'Packet Delimiter Character'* settings. However, the user can adjust no bytes within the response sent back by the radio.

TDMA Packetized Commands

1. ‘0’ Tell local radio to return its radio ID.

Command general description:

Addressee is a local radio or a remote radio	Local

Command format:

0xDD,0x00,0x01,0x00,0x30

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x01	Command length	No
0x30	Command code	No

Command example:

0x770x000x010x000x30

Output format (at the local radio):

0xDD,0x00,0x04,0x00,0x30,0x##0x##0x##

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	No
0x04	Command length	No
0x30	Command code	No
0x## 0x## 0x##	Local radio’s 3 byte ID number	No

Output string example (at the local radio):

0x770x000x040x000x300x890x590x12

2. '1' EEPROM individual address write and read command.
EEPROM write command format:

Command general description:

Addressee is a local radio or a remote radio	Local

Radio will reset after reception of the program command, and will re-acquire the network, assuming no network sensitive parameters were changed.

EEPROM write command format:

0xDD,0x00,0x05,0x00,0x31,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x31	Command code	No
0x01	Write operation	No
0xMSB Address	The MSB of the EEPROM address where the data will be stored (*)	Yes
0xLSB Address	The LSB of the EEPROM address where the data will be stored (*)	Yes
####(data)	Data (hex value) to be loaded starting from Address specified above (one byte)	Yes

(*) Note: The address could be one from the list below:
0x0D81, 0x0D82, 0x0D85 … 0x0F41, 0x0F73 … 0x0FFF

EEPROM write command example:

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- we need to store 0x20 in the 0x0F2E location;

then the command will be:

0x770x000x050x000x310x010x0F0x2E0x20

Output format[1]:

0xDD,0x00,0x05,0x00,0x31,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x05	Command length	No
0x31	Command code	No
0x01	Write operation	No
0xMSB Address	The MSB of the EEPROM address where the data will be	No

	stored (*)	
0xLSB Address	The LSB of the EEPROM address where the data will be stored (*)	No
####(data)	Data (hex value) to be loaded starting from Address specified above (one byte)	No

Output string example (at the local radio):

If
- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x20 was stored at the address 0x0F2E;

then the command will be:

0x770x000x050x000x310x010x0F0x2E0x20

EEPROM read command format:

0xDD,0x00,0x05,0x00,0x31,0x00,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x31	Command code	No
0x00	Read operation	No
0xMSB Address	The MSB of the EEPROM address, which we want to read the data from (*)	Yes
0xLSB Address	The LSB of the EEPROM address, which we want to read the data from (*)	Yes
####(data)	Dummy data (hex value), one byte only	Yes

(*) Note: The address could be one from the list below:
0x0D81, 0x0D82, 0x0D85 … 0x0F40, 0x0F73 … 0x0FFF

EEPROM read command example:

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- we need to read 0x0F2E location contents;
- 'FF' being dummy data byte;

then the command will be:

0x770x000x050x000x310x000x0F0x2E0xFF

Output format[1]:

0xDD,0x00,0x05,0x00,0x31,0x00,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x05	Command length	No
0x31	Command code	No
0x00	Read operation	No
0xMSB Address	The MSB of the EEPROM address, which we want to read the data from (*)	No
0xLSB Address	The LSB of the EEPROM address, which we want to read the data from (*)	No
####(data)	Actual data being read from the specified EEPROM location, one byte only	No

Output string example (at the local radio):

If

- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x20 was stored at the address 0x0F2E;

then the command will be:

0x770x000x050x000x310x000x0F0x2E0x20

Reading or Writing to invalid EEPROM locations will have the Output string:

0xDD,0x00,0x02,0x00,0x31,0x01

3. '2' RAM individual address write and read command.
RAM write command format:

Command general description:

Addressee is a local radio or a remote radio	Local

RAM write command format:

0xDD,0x00,0x05,0x00,0x32,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	**Meaning/format**	**User adjustable**
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x32	Command code	No
0x01	Write operation	No
0xMSB Address	The MSB of the RAM address where the data will be stored (*)	Yes
0xLSB Address	The LSB of the RAM address where the data will be stored (*)	Yes
####(data)	Data (hex value) to be written to the specified RAM location (one byte only)	Yes

(*) Note: The address could be one from the range below:
5800 … 5900 – TDMA Frame Table

RAM write command example:

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- we need to store 0x20 in the 0x58FE location;

then the command will be:

0x770x000x050x000x320x010x580xFE0x20

Output format:

0xDD,0x00,0x05,0x00,0x32,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	**Meaning/format**	**User adjustable**
0xDD	Delimiter (hex value)	No
0x05	Command length	No
0x32	Command code	No
0x01	Write operation	No
0xMSB Address	The MSB of the RAM address where the data will be stored	No

	(*)	
0xLSB Address	The LSB of the RAM address where the data will be stored (*)	No
####(data)	Data (hex value) to be written to the specified RAM location (one byte only)	No

Output string example (at the local radio):

If

- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x20 was stored at the address 0x58FE;

then the command will be:

0x770x000x050x000x310x010x580xFE0x20

RAM read command format:

0xDD,0x00,0x05,0x00,0x32,0x00,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x32	Command code	No
0x00	Read operation	No
0xMSB Address	The MSB of the RAM address, which we need to read the data from (*)	Yes
0xLSB Address	The LSB of the RAM address, which we need to read the data from (*)	Yes
####(data)	Dummy data (hex value), one byte only.	Yes

(*) Note: The address could be one from the range below:
5800 … 5900 – TDMA Frame Table

RAM read command example:

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- we need to read 0x58FE location contents;
- 'FF' being dummy data byte;

then the command will be:

0x770x000x050x000x310x000x580xFE0xFF

Output format:

0xDD,0x00,0x05,0x00,0x32,0x00,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x05	Command length	No
0x32	Command code	No
0x00	Read operation	No
0xMSB Address	The MSB of the RAM address, which we need to read the data from (*)	No
0xLSB Address	The LSB of the RAM address, which we need to read the data from (*)	No
####(data)	Data (hex value) read form the specified RAM location (one byte only)	No

Output string example (at the local radio):

If

- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x20 was stored at the address 0x58FE;

then the command will be:

0x770x000x050x000x310x000x580xFE0x20

Network ID and Frequency Key RAM write command format:

Allows a radio to switch between two networks that have similar settings. The radio will receive the command, process it, and drop the link. Then the radio will attempt to link to a network with the new Frequency Key and Network ID.

This option was added in firmware versions:
DGR 5.85
DGMR 1.85

* Frame Table Reset On Disconnect must be disabled, as radio will change the parameters, disconnect, and re-acquire the network (or new network).

0xDD,0x00,0x05,0x00,0x32,0x03,0x58,0xFF,0xNN

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x32	Command code	No
0x03	Frequency Key and Network ID operation	No
0x58	Dummy Byte	No
0xFF	Frequency Key	Yes
0xNN	Network ID	Yes

*** Note:** The Frequency Key should be between $00 and $0E.
The Network ID should be between $00 and $FF.

Output format:

0xDD,0x00,0x05,0x00,0x32,0x03,0xFF,0xNN,0xXX

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x05	Command length	No
0x32	Command code	No
0x03	Frequency Key and Network ID operation	No
0xFF	Frequency Key set in RAM	No
0xNN	Network ID set in RAM	No
0xXX	Dummy Byte	No

Network ID and Frequency Key RAM write command example:

If
- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- The frequency key should be set to 6
- The network ID should be set to 42

then the command will be:

0x770x000x050x000x320x030x580x060x2A

Output string example (at the local radio):

0x770x000x050x000x320x030x060x2A0xAA

4. 'D' Disconnect and Connect status message.

The TDMA parameter 'Disconnect Message' needs to be set for this feature.

Command general description:

Addressee is a local radio or a remote radio	Local

Note: 'Disconnect' message is not available on the master.

Output format (at the local radio): Disconnect

0xDD,0x00,0x02,0x00,0x44,0x##

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x02	Command length	No
0x44	Command code	No
0x##	If this location has '00' in it, then the radio has being just turned on or the radio lost sync to the master for the first time. If there is a number in this location, that is the number of times the slave or submaster has lost sync and disconnected from the network to require a sync signal.	No

Output string example (at the local radio):

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- the local radio just power up;

then the output string will be:

0x770x000x020x000x440x00

If
- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';
- the local radio has been powered up for a long time and had 20 (0x14) disconnects during this time;

then the output string will be:

0x770x000x020x000x440x14

Output format (at the local radio): Connect

0xDD,0x00,0x01,0x00,0x45

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No

0x01	Command length	No
0x45	Command code – the submaster or slave has found a synch signal from the master and has connected to the network.	No

Output string example (at the local radio):

If
- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- the local radio just power up;

then the output string will be:

0x770x000x010x000x45

5. 'S' Tell local radio to go into the setup mode.

Command general description:

Addressee is a local radio or a remote radio	Local

Command format:

0xDD,0x00,0x01,0x00,0x53

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x01	Command length	No
0x53	Command code	No

Note: After the command will be executed, the RS232 baud rate in setup mode will be the same as it was before the setup.

Command example:

0x770x000x010x000x53

Output format (at the local radio):

Radio returns its Main Menu text.

6. ‘`’ Bulk load of EEPROM TDMA Settings, TDMA Frame Table and Frequency table.
Write command format:

Command general description:

Addressee is a local radio or a remote radio	Local

After reception of program command, the radio will reset, and assuming no network sensitive parameters were changed, re-acquire the network.

Write command format:

0xDD,0x00,0x4+data size,0x00,0x60,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x04 + data size	Number of data bytes plus 4	Yes
0x60	Command code	No
0x01	write operation	No
0xMSB Address	Start writing at this address (MSB of this address) (*)	Yes
0xLSB Address	Start writing at this address (LSB of this address) (*)	Yes
####(data)	data (hex value) to be loaded starting from Address specified above	Yes

(*) Note: The address could be one from the list below:
E25 – F2E TDMA settings including TDMA frame table.
F74 – FFD Frequency hop table.

Note: For 225-400 MHz radios this hop table starts at F74 (please, refer to “225-400 MHz radios EEPROM Value to Frequency Calculations” for more details).

Write command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- we need to store 0x02 at E26 and 0x12 at E27;

then the command will be:

0x770x000x060x000x600x010x0E0x250x020x12

Output format (at the local radio)[2]:

0xDD,0x00,0x4+data size,0x00,0x60,0x01,0xMSB Address,0xLSB Address,#####(data)

Output string example (at the local radio):

If

- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x02 was stored at 0x0E26 and 0x12 was stared at 0x0E27;

then the command will be:

0x770x000x060x000x600x010x0E0x250x020x12

Read command format:

0xDD,0x00,0x6,0x00,0x60,0x00,0xStart MSB address, 0xStart LSB address,0xEnd MSB address,0xEnd LSB address

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x06	Command length	No
0x60	Command code	No
0x00	read operation	No
0xStart MSB Address	Start reading at this address (MSB of this address) (*)	Yes
0xStart LSB Address	Start reading at this address (LSB of this address) (*)	Yes
0xEnd MSB Address	Stop reading at this address (MSB of this address) (*)	Yes
0xEnd LSB Address	Stop reading at this address (LSB of this address) (*)	Yes

(*) Note: The address could be one from the list below:
E25 – F2E TDMA settings including TDMA frame table.
F74 – FFD Frequency hop table.
Maximum allowable length, 140 EEPROM addresses.

Note: For 225-400 MHz radios this hop table starts at F74 (please, refer to “225-400 MHz radios EEPROM Value to Frequency Calculations” for more details).

Read command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- we need to read from 0x0E30 to 0xE32;

then the command will be:

0x770x000x060x000x600x000x0E0x300x0E0x32

Output format[2]:

0xDD,0x00,0x4+data size,0x00,0x60,0x00,0xStart MSB Address,0xStart LSB Address,#####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x04+data size	Number of data bytes plus 4	No
0x60	Command code	No
0x00	read operation	No
0xStart MSB Address	Start reading at this address (MSB of this address) (*)	No
0xStart LSB Address	Start reading at this address (LSB of this address) (*)	No

Output string read command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- we read from 0x0E30 to 0xE32;
- the data read was ‘0x01’, ‘0x0D’, and ‘0xFE’;

then the command will be:

0x770x000x070x000x600x000x0E0x300x0E0x320x010x0D0xFE

Reading or Writing to invalid EEPROM locations will have the Output string:

0xDD,0x00,0x02,0x00,0x60,0x01

7. ‘a’ Bulk load of frame table into RAM.
Write command format:

Command general description:

Addressee is a local radio or a remote radio	Local

Frame table reset on disconnect is of special interest with this command. If the frame table reset option is set, then any time the radio loses the link, the frame table will default back to that stored in EEprom. If the frame table reset option is not set, then the radio will keep the frame table in RAM until loss of power, upon which the radio will default back to the frame table stored in EEprom.

0xDD,0x00,0x4+data size,0x00,0x61,0x01,0xMSB Address,0xLSB Address,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x04 + data size	Number of data bytes plus 4	Yes
0x61	Command code	No
0x01	Write operation	No
0xMSB Address	Start writing at this address (MSB of this address) (*)	Yes
0xLSB Address	Start writing at this address (LSB of this address) (*)	Yes
####(data)	Data (hex value) to be loaded starting from Address specified above	Yes

(*) Note: The address could be one from the list below:
5800 – 5900 Temporary TDMA frame table..
Write command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- we need to store 0x20 in the frame ‘01’ on the radio;

then the command will be:

0x770x000x050x000x610x010x580x010x20

Output format (at the local radio)[3]:

0xDD,0x00,0x4+data size,0x00,0x61,0x01,0xMSB Address,0xLSB Address,#####(data)

Output string example (at the local radio)[3]:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- 0x20 was stored at the address 0x5801 (frame ‘01’);

then the command will be:

0x770x000x050x000x610x010x580x010x20

Read command format:

0xDD,0x00,0x6,0x00,0x61,0x00,0xStart MSB address, 0xStart LSB address,0xEnd MSB address,0xEnd LSB address

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x06	Command length	No
0x61	Command code	No
0x00	read operation	No
0xStart MSB Address	Start reading at this address (MSB of this address) (*)	Yes
0xStart LSB Address	Start reading at this address (LSB of this address) (*)	Yes
0xEnd MSB Address	Stop reading at this address (MSB of this address) (*)	Yes
0xEnd LSB Address	Stop reading at this address (LSB of this address) (*)	Yes

Read command example:

If
- the Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119';
- we need to read frames '01' (at the address 0x5801) through '03' (at the address 0x5803);

then the command will be:

0x770x000x060x000x610x000x580x010x580x03

Note: maximum allowable EEPROM read length is 140 EEPROM locations.

Output format[3]:

0xDD,0x00,0x4+data size,0x00,0x61,0x00,0xMSB Address,0xLSB Address,#####(data)

Output string read command example:

If
- the Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119';
- we read from 0x5801 (frame '01') to 0x5803 (frame '03');
- the data read was '0x00', '0x20', and '0x21';

then the command will be:

0x770x000x070x000x610x000x580x010x000x200x021

Reading or Writing to invalid EEPROM locations will have the Output string:

0xDD,0x00,0x02,0x00,0x61,0x01

8. ‘b’ Tell local radio to respond with its signal quality packet.

Command general description:

Addressee is a local radio or a remote radio	Local

Command format:

0xDD,0x00,0x01,0x00,0x62

Field name	Meaning/format	User adjustable
0Xdd	Delimiter byte (hex value)	Yes
0x01	Command length	No
0x62	Command code	No

Command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’

then the command will be:

0x770x000x010x000x62

Output format (at the local radio):

0xDD,0x00,0x01+quality packet length,0x00,0x62,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value) of the local radio	No
0x01+quality packet length	1 plus number of bytes in the quality packet in hex format. For example, if the quality packet includes 4 bytes of data, then this location will be 0x05	No
0x62	Command code	No
####(data)	The actual quality packet data in hex format. Please, see **Note** below for more information about this item.	No

Note. The quality packet always consists of n = (2 * (# submasters + 1) + 1) bytes of data. The format of these data bytes is as follow:

- if there are no submasters in the network:

  DataByte1, DataByte2, DataByte3

- if there are one or more submasters in the network:

  DataByte1, DataByte2, DataByte3, … DataByte(2*i + 2), DataByte(2*i + 3)

where

i = 1, 2, 3, 4 …

is the number of submasters.

Table below shows DataBytes contents.

DataByte1	The average noise level at the local radio.
DataByte2	Percentage of packets sent from the master, which were successfully decoded by the local radio (during the frame #00, slot #0).
DataByte3	Average signal level measured by the local radio during master's transmission (during the frame #00, slot #0).
DataByte(2*i + 2)	Percentage of packets sent from submaster 'i', which were successfully decoded by the local radio (during the frame #00, slot #i).
DataByte(2*i + 3)	Average signal level measured by local radio during submaster's 'i' transmission (during the frame #00, slot #i).

Output string example (at the local radio):

If

- the Delimiter on the local radio is set to '0x77', which will appear in the TDMA menu as '119';
- there are no submasters in the system (*Number of SubMaster* in the TDMA menu is set to '0');
- **the local radio is a slave**;
- *RadioStatistics Menu* on the local radios reads '29' for average noise level. Please, note that actual average noise value returned by the local radio will be greater than shown in the *RadioStatistics* by 16:
  29 + 16 = 45, or
  0x1D + 0x10 = 0x2D;
- the percentage of master packets successfully decoded by the local radio is 95% (0x5F);
- the average signal level measured by local radio during master's transmission (frame #00, slot #0) is '87' (0x57);

Then the output string will be:

0x770x000x040x000x620x2D0x5F0x57

If the local radio is the master, the last two bytes (0x5F and 0x57 above) will be 0x00 and 0x00.

If

- the delimiter on the local radio is set to '0x77', which will appear in the TDMA menu as '119';
- there are two submasters in the system (*Number of SubMasters* in the TDMA menu is set to '2');
- **the local radio is the first submaster** (its frame table has '31' or '21' in the frame #00);
- *RadioStatistics Menu* on the local radios reads '29' for average noise level. Please, note that actual average noise value returned by the local radio will be greater than shown in the *RadioStatistics Menu* by 16:
  29 + 16 = 45, or
  0x1D + 0x10 = 0x2D;
- the percentage of master packets successfully decoded by the local radio is 95% (0x5F);
- the average signal level measured by local radio during master's transmission (frame #00, slot #0) is '87' (0x57);

- the percentage of packets sent from submaster 2 and successfully decoded by the local radio is 99% (0x63);
- the average signal level measured by local radio during transmission of submaster 2 (frame #00, slot #2) is ‘85’ (0x55);

Then the output string will be:

0x770x000x080x000x620x2D0x5F0x570x000x000x630x55

positions in the packet, which correspond to decode success and average signal level of the radio whose signal quality packet was requested (the first submaster in our case).

Notes:

- The packet will include zeros in the position of the radio whose signal quality packet was requested.
- The average signal level from x radio is only updated when x radio is heard. Therefore, if x radio is turned off, the average signal level will still show the previous average and its packet decode success will drop to zero.

9. ‘c’ Get radio’s firmware version number.

Command general description:

Addressee is a local radio or a remote radio	Local

Command format:

0xDD,0x00,0x01,0x00,0x63

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x01	Command length	No
0x63	Command code	No

Command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;

then the command will be:

0x770x000x010x000x63

Output format (at the local radio):

0xDD,0x00,0x03,0x00,0x63,0x##0x##

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x03	Command length	No
0x63	Command code	No
0x## 0x##	F/w version extension. For example, if the radio has “5.58” version of f/w, it will return 0x350x38	No

Output string example (at the local radio):

If
- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- the local radio has 5.58 version of the f/w;
- the output characters are the ASCII codes of the decimal places of the firmware version, 0x36 is the ASCII code for 6, and 0x38 is the ASCII code for 8.

then the output string will be:

0x770x000x030x000x630x360x38

Note:

The output may only have one return value, and there is a lookup table available from FreeWave. Here is the current table as of the writing of this manual.

In this case the output will be, given firmware of 5.85:

0x770x000x020x000x630x69

DGR

Firmware Ver.	TDMA Command value Decimal	TDMA Command value Hexadecimal
5.63	63	3F
5.64	64	40
5.65	65	41
5.67g	71	47
5.68	73	49
5.74	91	5B
5.75	93	5D
5.76	94	5E
5.77	95	5F
5.79	97	61
5.80	98	62
5.81	99	63
5.82	102	66
5.84	104	68
5.85	105	69

FGR

Firmware Ver.	TDMA Command value Decimal	TDMA Command value Hexadecimal
2.21	21	15

10. '7' Tell remote radio to respond with its signal quality packet on specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Command restrictions:

Can be issued only from the master.

Terminology used:

Remote radio of interest will be called 'addressee'.

Command format:

0xDD,0x00,0x05,0x00,0x37,0x## 0x##,0x##,0xNN

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x37	Command code	No
0x## 0x## 0x##	Addressee's 3 byte address	Yes
0xNN	Frame number in hex format	Yes

Command example:

If
- the Delimiter on the local radio (master) is set to '0x77', which will appear in the TDMA Menu as '119';
- the addressee's serial number is '900-1234' (0x890x590x12);
- the frame number will need to used for the '900-1234' radio's response is '05'

then the command will be:

0x770x000x050x000x370x890x590x120x05

After this command will be received by the radio '900-1234', it will send its quality packet on the frame 05.

Output format (at the master radio):

0xDD,0x00,0x04+quality packet length,0x00,0x37,0x## 0x##,0x##,####(data)

Field name	Meaning/format	User adjustable

0Xdd	Delimiter byte (hex value) of the addressee	No
0x04+quality packet length	4 plus number of bytes in the quality packet in hex format. For example, if the quality packet includes 3 bytes of data, then this location will be 0x07	No
0x37	Command code	No
0x## 0x## 0x##	Addressee's 3 byte address	No
####(data)	The actual quality packet data in hex format	No

Note. The quality packet always consists of n = (2 * (# submasters + 1) + 1) bytes of data. The format of these data bytes is as follow:

· if there are no submasters in the network:

DataByte1, DataByte2, DataByte3

· if there are one or more submasters in the network:

DataByte1, DataByte2, DataByte3, … DataByte(2*i + 2), DataByte(2*i + 3)

where

i = 1, 2, 3, 4 …

is the number of submasters.

Table below shows DataBytes contents.

DataByte1	The average noise level at addressee radio.
DataByte2	Percentage of packets sent from the master, which were successfully decoded by addressee (during the frame #00, slot #0).
DataByte3	Average signal level measured by the addressee during master's transmission (during the frame #00, slot #0).
DataByte(2*i + 2)	Percentage of packets sent from submaster 'i', which were successfully decoded by the addressee (during the frame #00, slot #i).
DataByte(2*i + 3)	Average signal level measured by the addressee during submaster's 'i' transmission (during the frame #00, slot #i).

Output string example (at the master radio):

If

- the Delimiter on the addressee is set to '0x77', which will appear in the TDMA menu as '119';
- the addressee has serial number 900-1234 (0x890x590x12);
- **the addressee is a slave;**
- there are no submasters in the system (*Number of SubMaster* in the TDMA menu is set to '0');
- *RadioStatistics Menu* on the addressee reads '29' for average noise level. Please, note that actual average noise value returned by the addressee will be greater than shown in the *RadioStatistics* by 16:

  29 + 16 = 45, or

  0x1D + 0x10 = 0x2D;
- the percentage of master packets successfully decoded by the addressee is 95% (0x5F);

- the average signal level measured by the addressee during master's transmission (frame #00, slot #0) is '87' (0x57);

Then the output string will be:

0x770x000x070x000x370x890x590x120x2D0x5F0x57

If

- the delimiter on the addressee is set to '0x77', which will appear in the TDMA menu as '119';
- the addressee has serial number 900-1234 (0x890x590x12);
- there are two submasters in the system (*Number of SubMasters* in the TDMA menu is set to '2');
- **the addressee is the second submaster**;
- *RadioStatistics Menu* on the addressee reads '29' for average noise level. Please, note that actual average noise value returned by the addressee will be greater than shown in the *RadioStatistics Menu* by 16:
  29 + 16 = 45, or
  0x1D + 0x10 = 0x2D;
- the percentage of master packets successfully decoded by the addressee is 95% (0x5F);
- the average signal level measured by addressee during master's transmission (frame #00, slot #0) is '87' (0x57);
- the percentage of packets sent from submaster 2 and successfully decoded by the addressee is 99% (0x63);
- the average signal level measured by addressee during transmission of submaster 2 (frame #00, slot #2) is '85' (0x55);

Then the output string will be:

0x770x000x0B0x000x370x890x590x120x2D0x5F0x570x630x550x000x00

positions in the packet, which correspond to decode success and average signal level of the radio whose signal quality packet was requested (the second submaster in this case).

Notes:

- The packet will include zeros in the position of the radio whose packet was requested.
- The average signal level from x radio is only updated when x radio is heard. Therefore, if x radio is turned off, its average signal level will still show the previous value and its packet decode success will drop to zero.
- Does not work for local radio.

11. 'B' Tell remote radio to transmit a status packet on specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Echoed out at all radios (that are programmed to listen in the frame table), except queried radio.

Command format:

0xDD,0x00,0x05,0x00,0x42,0x## 0x##0x##,0xNN

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x42	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address	Yes
0xNN	Frame number in hex format	Yes

Command example:

If
- the Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119';
- the remote radio's serial number is '900-1234' (0x890x590x12);
- the frame number will need to used for the '900-1234' radio's response is '05'

then the command will be:

0x770x000x050x000x420x890x590x120x05

After this command will be received by the radio '900-1234', it will send its status packet on the frame 05.

Output format (at the local radio):

0xDD,0x00,0x07,0x00,0x42,0x## 0x##0x##,0xVt,0xTp,0xRD

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	No
0x07	Command length	No
0x42	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address	No
0xVt	Byte of data that corresponds to the sample of radio's input DC voltage measurements with 15VDC being a full scale.	No
0xTp	Byte of data that corresponds to the sample of radio's temperature measurements. *Note: use given below formulas to convert this Hex value into deg. C.*	No
0xRD	Byte of data that corresponds to the status of RTS and DTR inputs on the radio. Bit 7 (MSB) is the RTS line and Bit 4 is	No

	the DTR line. “1” corresponds to a low level on these pins.	

Output string example (at the local radio):

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- the remote radio’s serial number is ‘900-1234’ (0x890x590x12);
- the input DC voltage measured by the radio is 12VDC (0xCC);
- the radio’s temperature 25 deg. C (0x80);
- RTS is low and DTR is high (0x10);

then the output string will be:

0x770x000x070x000x420x890x590x120xCC0x800x10

Use listed below algorithm to convert ‘0xTp’ value into deg. Centigrade:

- Convert 0xTp readings from the radio into an integer number (Temp%).
- Make sure that the value of ‘0xTp’ after conversion is between 6 and 255.
- Calculate the result as follows:
  Temp% = Temp%/256
  Temp% = (Temp% * 22) / ((1 – (Temp%/256)) * 25)
  Temp% = (-0.0196 + SQR(0.0196^2 + 4 * LOG10(Temp%) * 0.000057))
  Temp% = Temp% / (2 * 0.000057)
  Temp% = 25 – Temp%

Note: Does not work for local radio.

12. 'F' Special Data Packet command.

Sends data to a specific radio or radios on a specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Ignores delimiter characters inside the data packet. This command is suitable for 'random' binary data.

Command format:

0xDD,0x00,0x05+data size,0xEC,0x46,0x##0x##0x##,0xNN,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05+0xdata size	Number of data bytes plus 5 in hex format. For example, if the command includes 4 bytes of data in the end, then this location should be 0x09	Yes
0xEC	$00 for epoch reference, $01 for frame casing reference. **See note.**	Yes
0x46	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address	Yes
0xNN	Frame number to send command on	Yes
####(data)	The actual data being sent in hex format	Yes

Command example:

If
- the Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119';
- the remote radio's serial number is '900-1234' (0x890x590x12);
- the frame number will need to used to send data is '05';
- the data needs to be sent is '123456789A';

then the command will be:

0x770x000x0E0x000x460x890x590x120x050x010x020x030x040x050x060x070x080x090x0A

Output format (at the remote radio):

0xDD,0x##0x##0x##,0xdata size,####(data)

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x## 0x## 0x##	Sending radio's 3 byte address	No
0xdata size	Number of data bytes in hex format. For example, if the command includes 4 bytes of data in the end, then this location should be 0x04	No
####(data)	The actual data being sent in hex format	No

Output string example (at the remote radio):

If

- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- the remote radio’s serial number is ‘900-1234’ (0x890x590x12);

then the output string will be:

0x770x890x590x120x0A0x010x020x030x040x050x060x070x080x090x0A

Note: When the destination radio is addressed, the radio will receive the message even if it was programmed to do nothing for that frame. If the destination address is all radios (hex address FF FF FF), only the radios programmed to listen will receive the message if there is a good link.

Note:

When the fourth byte is set to zero, the frame number specified in byte 9 is the index into the epoch. A further discussion is coming soon.

When the fourth byte is set to one, the frame number specified in byte 9 is the index into the frame casing. Allowable entries are 1 – “slave frames per master frame” setting. Sending zero will result in nothing, and sending a value higher than “slave frames per master frame” will lock up the local port indefinitely.

13. 'H' "Who's out there" command.

Command general description:

Each radio echoes the response out the local port, as well as across the TDMA network back to the requesting unit.

Addressee is a local radio or a remote radio	Remote

Command format:

0xDD,0x00,0x05,0x00,0x48,0xFF0xFF0xFF,0xF0

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x48	Command code	No
0xFF0xFF0xFF	Destination radio's 3 byte address – 0xFF0xFF0xFF means 'to anybody'	No
0xF0	Randomizing factor, FF is 100% response.	Yes

Command example:

If:

- the Delimiter on the local radio where the command is issued is set to '0x77', which will appear in the TDMA Menu as '119';

0x770x000x050x000x480xFF0xFF0xFF0xF0

Output format (at the local radio):

0xDD,0x00,0x04,0x00,0x48,0x## 0x##0x##

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	No
0x04	Command length	No
0x48	Command code	No
0x## 0x## 0x##	Responding radio 3 bytes ID number	No

Output string example (at the local radio):

0x770x000x040x000x480x890x590x12

Note: When this command is transmitted all radios that are listening will randomly transmit an acknowledgement over the next epoch. Every response will appear on RS232 output of the local radio in the order it was received. In the case of no collisions, the number of responses can be equal to the number of listening radios in the network. Repeating this command over should eventually result in a response from all radios in the network.

14. ‘L’ Tell remote radio to listen to all packets on specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Command format:

0xDD,0x00,0x05,0x00,0x4C,0x##0x##0x##,0xNN

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x4C	Command code	No
0x## 0x## 0x##	Destination radio’s 3 byte address.	Yes
0xNN	Frame number in hex format	Yes

Command example:

If:

· the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;

0x770x000x050x000x4C0x890x590x120x02

After this command will be received by the radio ‘900-1234’, its RAM copy of the frame table will have a new entry in the frame number 02, which is ‘10’.

Note: after the power will be recycled on the radio ‘900-1234’, the contents of the frame number 02 will be re-stored back to the value viewable from the TDMA Menu option ‘*Edit Xmit/Rcv Frames*’.

15. 'N' Tell remote radio to be idle on specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Command format:

0xDD,0x00,0x05,0x00,0x4E,0x##0x##0x##,0xNN

Field name	**Meaning/format**	**User adjustable**
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x4E	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address.	Yes
0xNN	Frame number in hex format	Yes

Command example:

If:

- The Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119'.
- If remote radio's serial number is '900-1234' (0x890x590x12),

then the command will be:

0x770x000x050x000x4E0x890x590x120x02

After this command will be received by the radio '900-1234', its RAM copy of the frame table will have a new entry in the frame number 02, which is '00'.

Note: after the power will be recycled on the radio '900-1234', the contents of the frame number 02 will be re-stored back to the value viewable from the TDMA Menu option '*Edit Xmit/Rcv Frames*'.

16. 'R' Tell remote radio to become a repeater/submaster.

Command general description:

Addressee is a local radio or a remote radio	Remote

Command format:

Tell remote radio to become a repeater
0xDD,0x00,0x06,0x00,0x52,0x##0x##0x##,0xNN,0xSS

or tell remote radio to become a submaster
0xDD,0x00,0x06,0x00,0x52,0x##0x##0x##,0x00,0xSS

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x06	Command length	No
0x52	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address.	Yes
0xNN	Frame number in hex format	Yes
0xSS	Slot number in hex format	Yes

Note: 0xNN is a frame number and 0xSS is a slot number to be used by the specified radio to repeat messages is hears within 0xNN frame on the slots before 0xSS.

Command example:

If:
- The Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119'.
- If remote radio's serial number is '900-1234' (0x890x590x12).

Then the command will be:

Tell remote radio '900-1234' to become a repeater

0x770x000x060x000x520x890x590x120x020x01

After this command will be received by the radio '900-1234', its RAM copy of the frame table will have a new entry in the frame number 02, which is '21'.

Note: after the power will be recycled on the radio '900-1234', the contents of the frame number 02 will be re-stored back to the value viewable from the TDMA Menu option '*Edit Xmit/Rcv Frames*'.

Tell remote radio '900-1234' to become a submaster

0x770x000x060x000x520x890x590x120x000x01

After this command will be received by the radio ‘900-1234’, its RAM copy of the frame table will have a new entry in the frame number 00, which is ‘31’.

Note: after the power will be recycled on the radio ‘900-1234’, the contents of the frame number 00 will be re-stored back to the value viewable from the TDMA Menu option ‘*Edit Xmit/Rcv Frames*’.

17. 'T' Tell remote radio to transmit on specified frame.

Command general description:

Addressee is a local radio or a remote radio	Remote

Command format:

0xDD,0x00,0x05,0x00,0x54,0x##0x##0x##,0xNN

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x05	Command length	No
0x54	Command code	No
0x## 0x## 0x##	Destination radio's 3 byte address.	Yes
0xNN	Frame number in hex format	Yes

Command example:

If:

- The Delimiter on the local radio is set to '0x77', which will appear in the TDMA Menu as '119'.
- If remote radio's serial number is '900-1234' (0x890x590x12).

Then the command will be:

0x770x000x050x000x540x890x590x120x02

After this command will be received by the radio '900-1234', its RAM copy of the frame table will have a new entry in the frame number 02, which is '20'.

Note: after the power will be recycled on the radio '900-1234', the contents of the frame number 02 will be re-stored back to the value viewable from the TDMA Menu option '*Edit Xmit/Rcv Frames*'.

18. ‘m’ Gather routing information from source radio to destination radio.

Command general description:

Addressee is a local radio or a remote radio	Local

Command format:

0xDD,0x00,0x05,0xx0,0x6D,0x##0x##0x##,0xFF

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	Yes
0x05	Command length	No
0x6D	Command code	No
0x## 0x## 0x##	Destination radio’s 3 byte address	Yes
0xFF	Frame number to send the command on	Yes

Command example:

If
- the Delimiter on the local radio is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;
- the remote radio’s serial number is ‘900-1234’ (0x890x590x12);
- the command has to be sent on the frame ‘05’ (0x05);

then the command will be:

0x770x000x050x000x6D0x890x590x120x05

Output format (at the local radio):

0xDD,0x00,0x05+number of slots,0x00,0x6D,0x##0x##0x##,0xFF,0xSS

Field name	Meaning/format	User adjustable
0xDD	Delimiter (hex value)	No
0x05 + number of slots	Command length starting after the first four bytes plus slot numbers sent on	No
0x6D	Command code	No
0x## 0x## 0x##	Destination radio’s 3 byte address	No
0xFF	Frame number to send the command on	No
0xSS	slot numbers sent on (example: 0x00,0x01,0x03 would refer to slot 0, slot 1 and slot3 is the route the command took.)	No

Output string example (at the local radio):

If
- the Delimiter on the local radio where the command is issued is set to ‘0x77’, which will appear in the TDMA Menu as ‘119’;

- the remote radio's serial number is '900-1234' (0x890x590x12);
- the frame used to send the command on was '05';
- the command travel through slot 0 -> slot 2 -> slot 5;

then the output string will be:

0x770x000x080x000x6D0x0890x590x120x050x000x020x05

19. Send data packet to a specified radio or broadcast.

Command general description:

Addressee is a local radio or a remote radio	Remote

Ignores delimiter characters in the data packet. This command is suitable for 'random' binary data.

Command format:

Send data packet to a specified radio as immediate data
0xDD,0x##0x##0x##,0xdata packet length,####(data),
where 0x##0x##0x## is different from local radio serial number and it is not 0xFF0xFF0xFF;

broadcast data packet and send it as assigned data
0xDD,0x##0x##0x##,0xdata packet length,####(data),
where 0x##0x##0x## is local's radio serial number;

or broadcast a data packet and send it as immediate data
0xDD,0xFF0xFF0xFF,0xdata packet length,####(data).

Field name	Meaning/format	User adjustable
0xDD	Delimiter byte (hex value)	Yes
0x## 0x## 0x##	Destination radio's 3 byte address. There are three options available: · This address is something different from local radio serial number and it is not '0xFF0xFF0xFF'. In this case the command will be sent as immediate data and will be addressed to a specified remote radio only. · This address is local's radio serial number. In this case the command will be sent as assigned data and will be addressed to all remote radios (broadcast). · This address is '0xFF0xFF0xFF'. In this case the command will be sent as immediate data and will be addressed to all remote radios (broadcast).	Yes
0xdata packet length	Number of data bytes to be sent	Yes
####(data)	Data packet in hex format	Yes

Command example:

If
- the local radio serial number is '900-1234' (0x890x590x12);
- one of the remote radio's serial number is '900-5678' (0x890x6A0x6E)

then the command will be:

Send '123456789A' data packet to the remote radio with serial number '900-5678' as immediate data

0x770x890x6A0x6E0x0A0x010x020x030x040x050x060x070x080x090x0A

The string on output of the ‘900-5678’ radio’s RS232 port if it was listening during the frame picked up by local radio for the transmission, will be:

0x770x890x6A0x6E0x0A0x010x020x030x040x050x060x070x080x090x0A

Broadcast ‘123456789A’ data packet to all remote radios and send it as assigned data

0x770x890x590x120x0A0x010x020x030x040x050x060x070x080x090x0A

The string on output of one of the remote radio, which heard this message during the frame assigned to the local radio, will be:

0x770x890x590x120x0A0x010x020x030x040x050x060x070x080x090x0A

Broadcast ‘123456789A’ data packet to all remote radios and send it as immediate data

0x770xFF0xFF0xFF0x0A0x010x020x030x040x050x060x070x080x090x0A

The string on the output of the RS232 port of all of the radios, which heard this message, will be:

0x770xFF0xFF0xFF0x0A0x010x020x030x040x050x060x070x080x090x0A

Appendix B - ASCII Table (dec, hex, char):

Table 11 ASCII, Hex, Dec Table

Dec	Hex	Char		Dec	Hex	Char		Dec	Hex	Char		Dec	Hex	Char
0	00	Null		64	40	@		128	80			192	C0	
1	01	SOH		65	41	A		129	81			193	C1	
2	02	STX		66	42	B		130	82			194	C2	
3	03	ETX		67	43	C		131	83			195	C3	
4	04	EOT		68	44	D		132	84			196	C4	
5	05	ENQ		69	45	E		133	85			197	C5	
6	06	ACK		70	46	F		134	86			198	C6	
7	07	BEL		71	47	G		135	87			199	C7	
8	08	BS		72	48	H		136	88			200	C8	
9	09	TAB		73	49	I		137	89			201	C9	
10	0A	LF		74	4A	J		138	8A			202	CA	
11	0B	VT		75	4B	K		139	8B			203	CB	
12	0C	FF		76	4C	L		140	8C			204	CC	
13	0D	CR		77	4D	M		141	8D			205	CD	
14	0E	SO		78	4E	N		142	8E			206	CE	
15	0F	SI		79	4F	O		143	8F			207	CF	
16	10	DLE		80	50	P		144	90			208	D0	
17	11	DC1		81	51	Q		145	91			209	D1	
18	12	DC2		82	52	R		146	92			210	D2	
19	13	DC3		83	53	S		147	93			211	D3	
20	14	DC4		84	54	T		148	94			212	D4	
21	15	NAK		85	55	U		149	95			213	D5	
22	16	SYN		86	56	V		150	96			214	D6	
23	17	ETB		87	57	W		151	97			215	D7	
24	18	CAN		88	58	X		152	98			216	D8	
25	19	EM		89	59	Y		153	99			217	D9	
26	1A	SUB		90	5A	Z		154	9A			218	DA	
27	1B	ESC		91	5B	[		155	9B			219	DB	
28	1C	FS		92	5C	\		156	9C			220	DC	
29	1D	GS		93	5D	]		157	9D			221	DD	
30	1E	RS		94	5E	^		158	9E			222	DE	
31	1F	US		95	5F	_		159	9F			223	DF	
32	20	Space		96	60	`		160	A0			224	E0	
33	21	!		97	61	a		161	A1			225	E1	
34	22	“		98	62	b		162	A2			226	E2	
35	23	#		99	63	c		163	A3			227	E3	
36	24	$		100	64	d		164	A4			228	E4	
37	25	%		101	65	e		165	A5			229	E5	
38	26	&		102	66	f		166	A6			230	E6	
39	27	‘		103	67	g		167	A7			231	E7	
40	28	(		104	68	h		168	A8			232	E8	
41	29	)		105	69	i		169	A9			233	E9	
42	2A	*		106	6A	j		170	AA			234	EA	
43	2B	+		107	6B	k		171	AB			235	EB	
44	2C	,		108	6C	l		172	AC			236	EC	
45	2D	-		109	6D	m		173	AD			237	ED	
46	2E	.		110	6E	n		174	AE			238	EE	
47	2F	/		111	6F	o		175	AF			239	EF	
48	30	0		112	70	p		176	B0			240	F0	
49	31	1		113	71	q		177	B1			241	F1	
50	32	2		114	72	r		178	B2			242	F2	
51	33	3		115	73	s		179	B3			243	F3	
52	34	4		116	74	t		180	B4			244	F4	
53	35	5		117	75	u		181	B5			245	F5	
54	36	6		118	76	v		182	B6			246	F6	
55	37	7		119	77	w		183	B7			247	F7	
56	38	8		120	78	x		184	B8			248	F8	
57	39	9		121	79	y		185	B9			249	F9	
58	3A	:		122	7A	z		186	BA			250	FA	

59	3B	;		123	7B	{		187	BB			251	FB	
60	3C	<		124	7C	|		188	BC			252	FC	
61	3D	=		125	7D	}		189	BD			253	FD	
62	3E	>		126	7E	~		190	BE			254	FE	
63	3F	?		127	7F			191	BF			255	FF	

Needs to be added:

- CD and CTS timings
- Test commands

Appendix C – Firmware Tables:

FGR Firmware.		
2.26	03-04-2003	Initial release.
2.27	04-28-2003	Added remote LED functionality.
2.30	07-28-2003	Added version of special data packet that references the frame casing instead of the epoch.
2.32	09-26-2003	Bug fix.
DGR Firmware.		
5.85	09-10-2002	Added version of Ram write command to load network ID and frequency key with one command.
5.87	03-02-2003	Bug Fix.
5.88	08-04-2003	Added version of special data packet that references the frame casing instead of the epoch.
DGMR Firmware.		
1.86	11-23-2002	Added version of Ram write command to load network ID and frequency key with one command.